January 1956

NUCLEONICS

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See page 30

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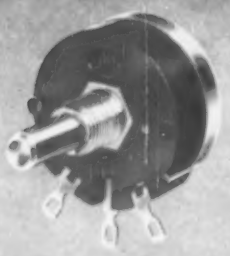

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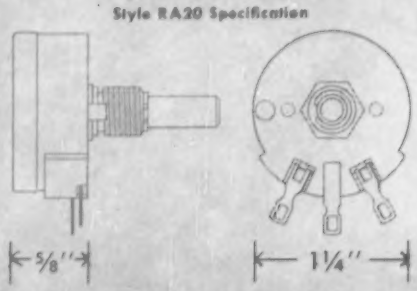

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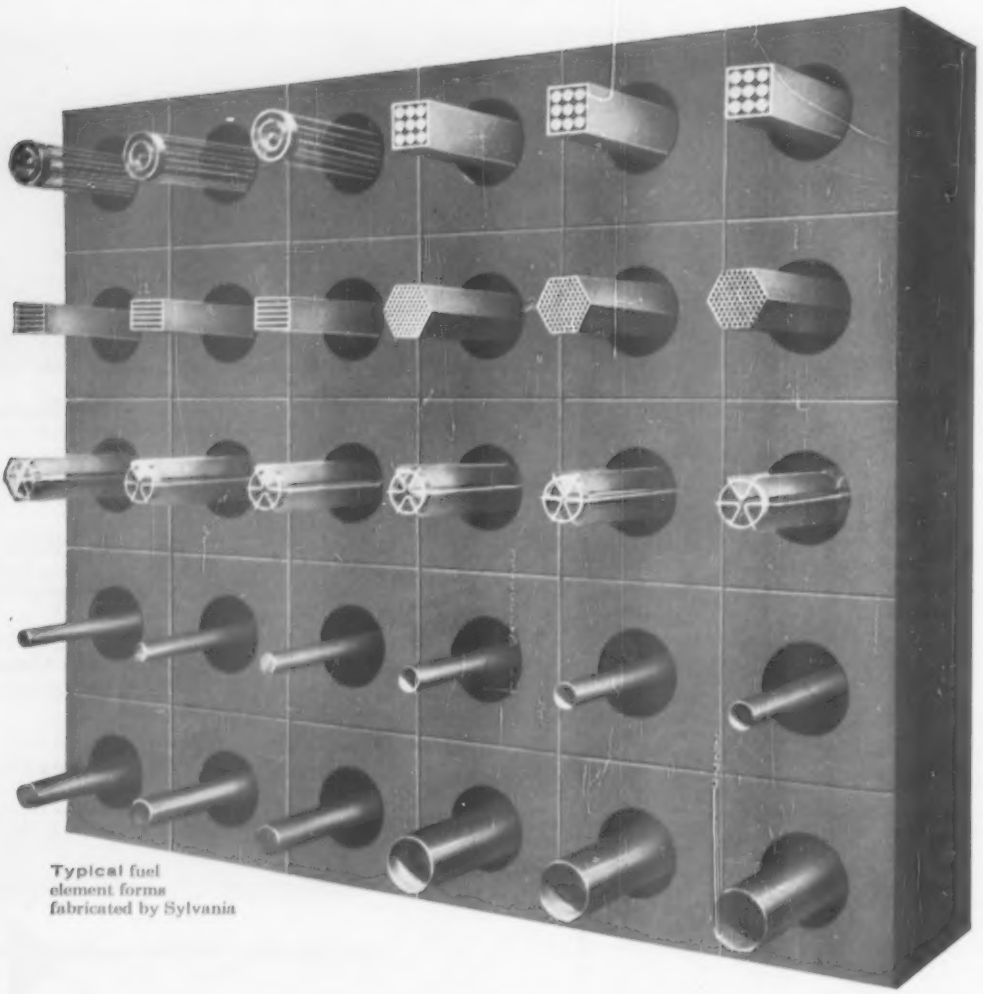

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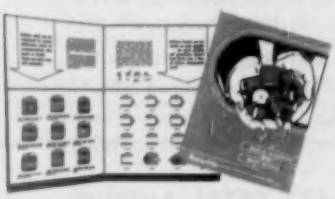

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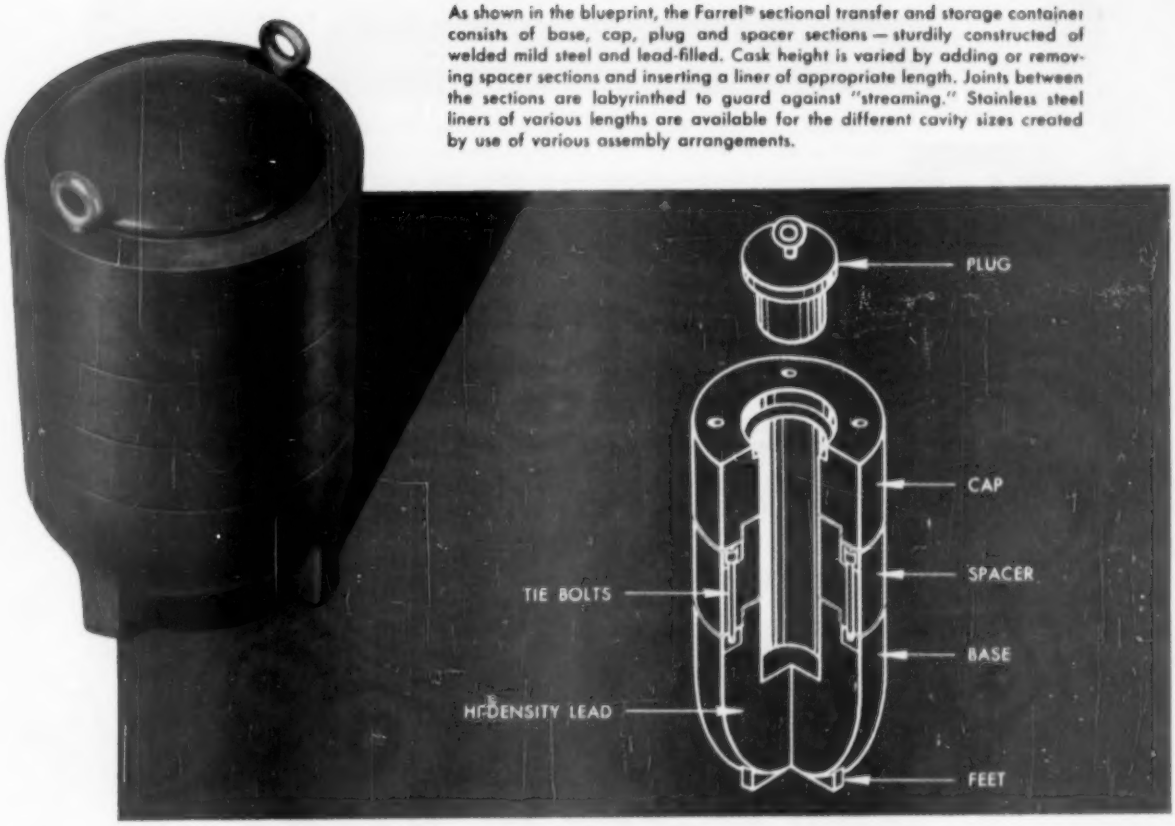

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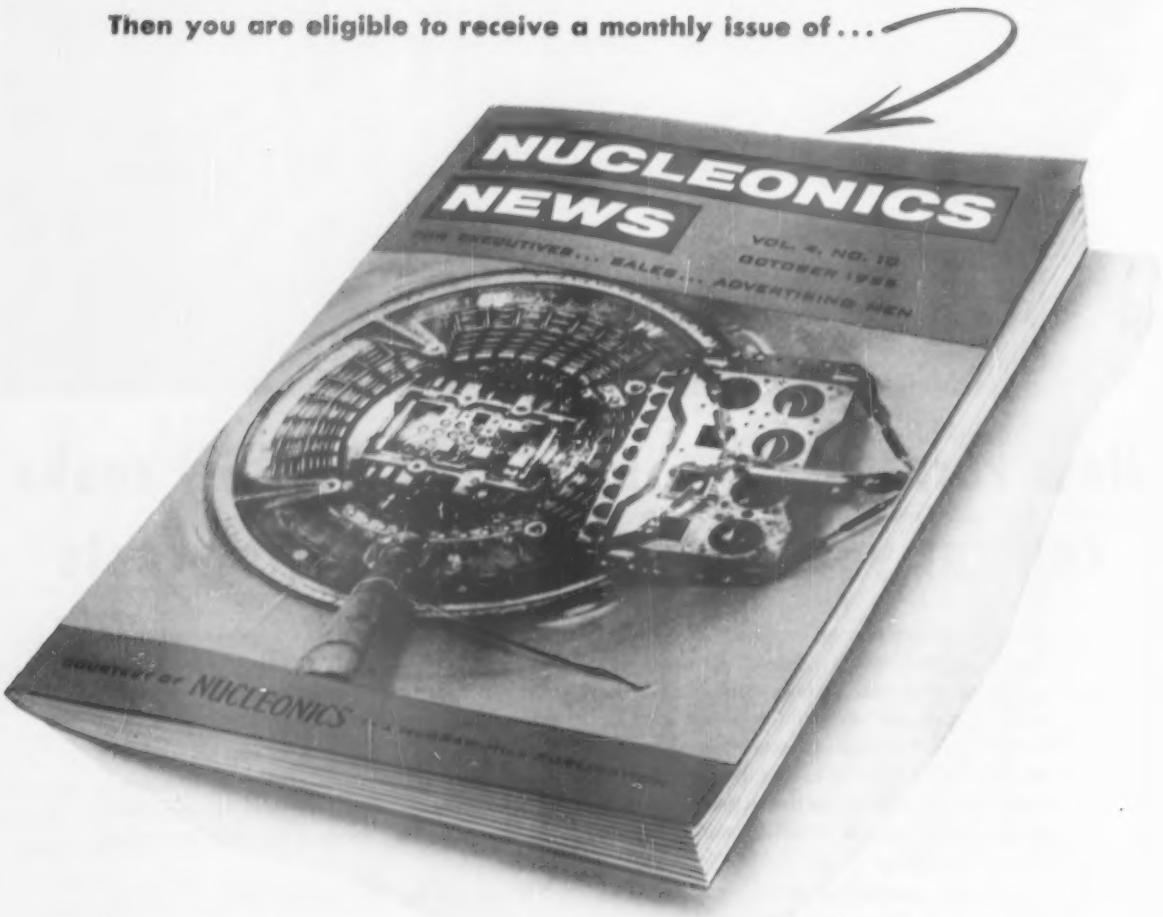

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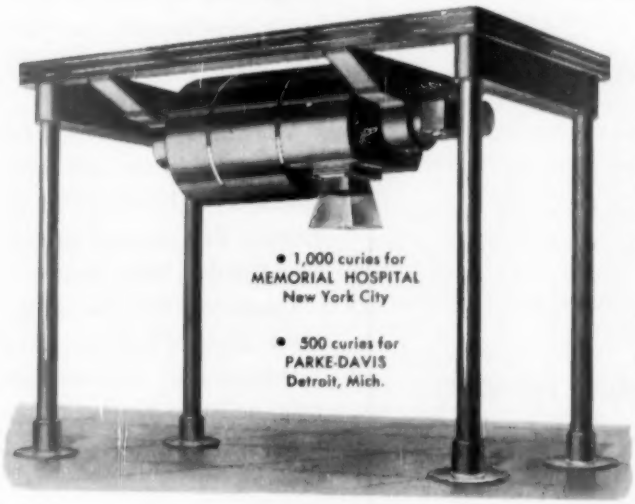

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ROUNDUP of Key Developments in Atomic Energy

LATE NEWS and Commentary

Radiation Legislation

Detailed advice to states on regulation of radiation exposure by legislative means is contained in Handbook 61 just published by the National Bureau of Standards. Drawn up by a committee headed by Lauriston Taylor, chairman of the National Committee on Radiation Protection, it includes a suggested State radiation protection act, suggested regulations, and the arguments for the philosophy embodied in the drafts. It warns that "confusion is well on its way" what with four different state approaches to the problem already undertaken and Federal licensing coming; urges enforceability as a prime criterion, in order to establish respect for control. Registration and spot-checking are recommended over licensing and inspection of all sources; however all kinds of ionizing radiation including X-rays should be covered by any act, to avoid confusion and conflict.

■

New Attack On Secrecy

In perhaps last year's sharpest attack on the secrecy policies of the Atomic Energy Commission, Senator Clinton P. Anderson, head of Congress' atomic watch-dog committee, challenged the AEC at Cleveland last month to do away with its entire access permit program and the "gray area" of classification as so much unnecessary restriction.

Widely reported by the newspapers was Anderson's remark: "It is easier for a camel to pass through the eye of a needle than it is for a businessman to receive frank, complete and unfettered answers from the Atomic Energy Commission."

But less attention was focused on these more significant, if less catchy, passages: "Why did we ever need access permits and clearances? Here are businessmen and scientists from all over the world talking about so-called secrets! But 10,000 people at home have been reading confidential material as I have. How long do they stay secrets? . . . For the present, anyway, we must attempt to live with the access permit program. Now exactly what do we accomplish by this procedure? I will pass over the question of whether such confidential information is worth guarding. I will ask instead if this whole complicated system of clearances keeps information out of the hands of our enemies—assuming they want it. Of course it doesn't. Are we to think that a foreign spy would necessarily have some sort of a police record showing him to have been an undesirable citizen or an embezzler when he asks an "L" clearance check? Hardly! Were not Burgess and MacLean people of good standing in the British Embassy?

"To me the access permit program is an example of supposed security which is not security at all. To me, this program can prove to be a stumbling block placed in the way of American industry—one more form to fill out, one more additional delay."

It was right to try to impose secrecy "when we first got into this atomic energy business," Anderson said. "We were then building weapons and the peaceful use of atomic energy was visible only on a distant horizon. Who could have guessed that the peaceful use would come so suddenly upon the world? But it did come, despite all our efforts at secrecy, and now the time is here for the curtain of secrecy to come down."

Although the JCAE chairman said he spoke only for himself, observers noted his plan for the group for this year (and particularly, in connection with the foregoing, his third point): "It is my hope that to carry out the mandate of the Atomic Energy Act of 1954, our Joint Committee will devote the early part of this coming session to three jobs with respect to the peaceful uses of atomic energy. First, to appraising the present and future impact of these applications

on the American way of life, economy, industry, and natural resources, including effect upon employment; second, to considering the impact of the atom on economies and industries abroad, as it will affect our economy and industry here at home; third, to studying the activities of the Atomic Energy Commission in its roles of developing and regulating the peaceful uses of atomic energy."

Other points made by Anderson at Cleveland:

Foreign competition: We face stiff competition in the international market from France, Britain, Russia, Italy, West Germany, where there are no hampering secrecy walls between government and industry; in addition, "they've come up with some ideas I did not find in my AEC reference library." Another reason why Americans may find it difficult to sell abroad: "They have to sell miles of red tape along with each reactor. Further, we insist that a foreign buyer bind himself to us for years while we reprocess his fuel elements and look over his shoulder."

Uranium control: "In the international atomic world uranium and thorium are available in just about any quantity you want. Yet in our country this government tells us what to do with uranium, and our uranium industry leads the sheltered life of a hothouse plant. No cold winds of competition from richer ores, more efficient processes and better ideas can blow across our domestic uranium industry from abroad. But hothouse plants fed on taxpayers' dollars are too feeble for rugged international competition."

Sale of waste: If asked to sell radioactive waste materials, Anderson said, AEC would reply, " 'No, we don't have any for sale. We haven't decided to sell them and even if we had, we couldn't quote you a price.' " (see p. 13).

Fusion secrecy: The Senator joined Dr. Henry D. Smyth and others in calling for an end to secrecy on controlled fusion: "I have heard no sound military reason advanced for keeping our work on this project classified. . . . It is my considered opinion that the time has now arrived when we should declassify, and not merely downgrade, all our work in the controlled hydrogen field."

•

Gamma-made Gasoline

Laboratory-scale experiments have successfully cracked crude oil to produce gasoline using gamma radiation, Esso Research & Engineering Co. officials said. The source was a 13-inch, 3,100-curie cobalt pipe that had spent two years in the Brookhaven reactor and was described as the most radioactive piece of material in use by industry. The source did not crack the crude by itself, but permitted a lesser application of the other three forces needed in refining: high temperature, high pressure and catalytic action. The tests were undertaken to see if gamma radiation could assist or replace these conventional forces; they may presage a day when crude could be put in a pipeline in Texas, be refined on the way in a radioactive section of pipeline, and come out as gasoline in New Jersey.

•

Nuclear Standards

Industry and government officials, 175 strong and representing most groups concerned with atomic radiation, met in Washington last month and agreed in short order to call on the American Standards Association for constitution of a "planning committee of experts." This body of 10 to 15 will study the need for standardization in the nuclear field, stake out and delimit the problems, and report back to the industry-government conference. They are to consider the effects of radiation on both people and materials. They may also recommend whether a new Nuclear Standards Board should be established within ASA to supervise the work of drawing up standards codes. GE's Vice-president Francis K. McCune, representing the Atomic Industrial Forum, said he hoped the planning committee would work "urgently, not at a routine, careful, slow pace."

Licensing, in Practice, Worries Industry; AEC Has Yet to Rule on Myriad Details

Now that commercial fabrication of reactor fuel elements has moved from a thing of the future to the here and now, private industry is beginning to worry about specific details. Especially is there concern about the location of that fine line that will divide AEC responsibilities from those of private licensed operators.

The number and variety of questions that can arise in this area are revealing both as to the nature of the problems that licensees will have to face, and as to the extent of the administrative vacuum that AEC has yet to fill by issuing policy guides.

Among the topics within that vacuum are such as these:

- **Accountability:** The new atomic energy act makes the fuel fabricating licensee responsible for keeping track of fissionable material it receives to be made up into reactor fuel elements for AEC or for private customers. This raises a host of problems as to the nature and frequency of reports the licensee must file with AEC, and what checks, if any, AEC will institute on the accuracy of such reports; what happens in the event of legitimate losses in production, or of dilution of enrichment.
- **Insurance:** The tough insurance problem of reactor operation liability has a counterpart in this field, as AEC has not announced whether it will require private fabricators to carry insurance on the value of inventory of fissionable material. Nor is it known whether such insurance is available, or what it would cost.
- **Exchange:** Since efficiency demands that fabricators run a unitized operation, they will need to know whether AEC will permit equivalent exchange of fissionable material between an AEC and a private job, or between two private jobs.
- **Scrap and waste:** Handling of U and U-alloy scrap metal and other industrial residues that might contain minute quantities of U must be clarified by the Commission. AEC has not said to what lengths fabricators must go to recover all possible fissionable material from scrap and waste; whether AEC itself will carry out the reprocessing of such scrap until a private licensee enters this business, and if so at what prices; what disposition would be made of waste that cannot be reprocessed economically; whether AEC will permit licensees to hold scrap in large quantities for extended periods, for business reasons; whether scrap from an AEC job that could meet an industrial requirement may be transferred for such use, and what AEC would charge for such material.

LMFR, Processing Interest Cleveland Congress

Interest in the liquid metal fueled reactor is running high. At least the fact is—although it is more likely to be the result of accident than of design—that of those papers presented at the Cleveland nuclear congress last month on specific reactor types, by far the greatest number—11 of 26, with only 5 for the runner-up—were about the LMFR. Of these, 3 were on design, 3 on liquid metal fuels, 4 on processing of such fuels, and 1 on LMFR physics.

Cost estimates on a 200-Mw LMFR power station showed a total estimated capital cost of $43.8-million and an energy cost of about 7½-mills/kwh. The capital cost figure includes items for land, interest during construction and other incidental costs, but does not include $4.7-million for initial uranium loading, $1.5-million for initial thorium blanket inventory, and $3-million for bismuth, sodium and NaK. The energy cost estimate assumes 80% load factor; 30-year depreciation on the turbine and 15 on the reactor-boiler; and that the annual fuel consumption cost would be limited to replacement of converted thorium. Annual processing plant operating costs of $2.5-million are assumed. If load factor can be lifted to 90%, energy cost comes down to 6.6 mills/kwh.

Brookhaven National Laboratory has been working along several lines on the reprocessing problem. One process described at Cleveland "scrubs" molten fuel alloy with molten salts which dissolve and retain the undesired fission products. The salt, after storage, can be purified for re-use. Another BNL process uses an alloy fuel so composed as to precipitate out pure U when sufficiently chilled. The U so concentrated is reconstituted into the correct alloying proportions and recycled.

The palm for the most unconventional reactor design idea of the week at Cleveland easily went to the Argonne team of H. H. Hyman and J. J. Katz. They described

AEC'S NEW HOME will look like this on completion in late 1957, according to a preliminary architect's sketch. The $10-million, four-story building will be located 23 air-miles northwest of present headquarters at 1901 Constitution Ave., Washington; work at the 109-acre site a mile from Germantown, Md., will begin in spring. In the left foreground, standing detached, is a 300-seat auditorium; extending from a wing at the rear left corner is a cafeteria. In the right rear is a service area including warehouse, garage, boiler house and cooling tower. Parking space for 800 cars will be provided on either side of the building. Visitors will enter at the front, employees from either side

a continuously processed heterogeneous reactor. This apparent self-contradiction is achieved by using as fuel a lattice of bare uranium pieces, randomly arranged within "columns" or "towers." Of moderate size, the pieces may take various shapes such as cylinders, spheres, pins, rings, wire spirals, etc., avoiding only shapes with a tendency to nest and thus reduce thermal contact. The uranium would be deliberately corroded in the circulating coolant—water, or possibly liquid metal—at a rate commensurate with the rate of fission-product formation. The wastes, dissolved in the coolant along with the U, would be removed by continuous processing. Fuel would be added by dropping more pieces onto the packed bed. The authors of this radical scheme claim for it advantages over both ordinary homogeneous and heterogeneous designs.

Other news highlights of the Cleveland technical sessions:

• **Chemical reprocessing:** Significant advances in the art were reported. One of them is a tiny, semiportable solvent extraction plant that can provide reliable results with as little as 100 cc of spent fuel. Another is an improvement in control over the operation of a pulse extraction column to prevent flooding, by means of a technique that predicts flooding caused by excessive pulsation. A cost study by Vitro for a solvent extraction plant handling slightly to highly enriched U alloyed with Zr estimated that for an invested capital of $3.72-million, 1,000-lb/day of spent fuel could be handled at an operating expense of about $3.84-million (figuring U-235 at $30/gm).

Pyroprocessing, as an alternative to aqueous solvent extraction, also came in for study. By cutting down on the long cooling period required before aqueous processing, pyrometallurgy can cut down fuel inventory; combining it with re-

Washington Report

Success of Euratom, the European atomic pool, will bring headaches to AEC. The U. S. agency will have to rearrange its policies to conform to State Dept. thinking, throwing open its reactor information files and turning loose greater quantities of special nuclear materials than are now provided for. AEC cannot buck the plan, which has Eisenhower's blessing and almost surely will receive support of Congress. So AEC will have to play along in declassifying for foreign consumption items still denied U. S. citizens. For it soon will become apparent that, when Europeans pool their resources, they can obtain power-reactor data and materials elsewhere, if denied U. S. aid.

Result will be a trend toward greater dissemination of technical information here. There will be less data reserved for the access permit program, and more totally declassified.

One pressure group formerly pushing hard for release of information has been largely eliminated as a driving force toward this end. Through its access permit plan—which makes available to "L" cleared persons almost all necessary reactor data—AEC has satisfied the incessant clamoring of private companies to be supplied with information and materials. In effect, AEC's reply to demands for declassification has been to "leak" information out to selected individuals, without making available for public consumption material which is talked about freely on other continents. Unfortunately, American industry has accepted this and to a large extent dropped its pressure for more declassification.

The real hope, then, for the few—chiefly scientists—who still cry out for an end to Federal control over nuclear data is Euratom. Which may focus attention on the fact that most of our classified information is available elsewhere if one knows where to go. The question will then arise why we have continued to hold under secrecy restrictions material ordered declassified by the Atomic Energy Act of 1954. The language of that act makes it clear that control of information shall be predicated on the national defense and security. Under no guise could continued control of information freely discussed in other countries be justified.

Euratom can be implemented without legislation. The 1954 act gives Congress enough latitude to supply such a pool with its essentials. AEC is also working on a new program of bilateral agreements with individual foreign nations covering power reactors, patterned after the liberal aid lines of the Belgian, British and Canadian agreements already in effect.

Congress will play a role in this declassification process. But it will be through political pressure, not legislative action, that its force will be felt. The same situation probably will prevail on other fronts in the atomic field, with the result that no important atomic legislation will be passed during the coming session.

There will be hearings, as required by the 1954 law. Much of the discussion will center on findings of the McKinney panel, which has been investigating for the JCAE the impact of atomic energy on the American economy. The groundwork for future legislative action will be laid during these talks.

One item sure to be discussed: the gradual separation of AEC's growing regulatory functions from its traditional manufacturing and development roles. Result is likely to be a gradual channeling of more authority to AEC's Civilian Applications Division, which handles licensing, until the division is ready to be set up as an independent regulatory body, much like the Federal Power Commission.

NEW YORK UNIVERSITY'S subcritical "pickle barrel reactor"—dubbed the PIKL Mark I by nuclear engineering students—has been installed in a basement on NYU's Bronx campus after being exhibited at the Cleveland atomic exposition. Essentially a neutron amplifier, it consists of 80 aluminum tubes containing 2 tons of natural uranium (worth $80,000 and allocated by the AEC) and a radium-beryllium neutron source (also loaned) supported in ordinary water (not vinegar!) as shielding. NYU's outlay for the teaching aid was only $5,000

mote fabrication can save as much as one-quarter to one-half the cost of an aqueous processing cycle, according to an Atomic Power Development Associates researcher. An Argonne team reported that oxidative slagging promised a "fast enough, efficient enough, cheap enough solution" to the problem, while a North American Aviation group reported on the relative advantages of other pyroprocessing methods (carbide slagging, volatilization, fused salt extraction, molten metal extraction, and fused salt electrolysis). Incidentally, it was revealed that EBR-II, the fast breeder to be built at Arco in the AEC five-year development program, would use pyroprocessing to recycle fuel, to cut down recycle time and to reduce the size and complexity of equipment. However, complete decontamination is not obtained, but the above-90% removal of fission product activity is considered acceptable.

A method, used at Hanford, for controlling an aqueous reprocessing operation by measuring radiation coming from process solutions was described by a Hanford engineer. Replacing slow and costly lab analyses of plant solutions, the system automatically draws periodic liquid samples into cells where gamma radiation from the samples is meas-

About the Industry

$279.28 will be the price of a single MTR fuel element made commercially by Babcock & Wilcox, the AEC disclosed. Under the contract it won (NU, Dec. '55, p. 10), B&W will fabricate 325 fuel assemblies for a total of $90,766. The B&W bid was lowest of 12 received; next lowest proposal was $385 per element, or $125,125 total. AEC will supply the highly-enriched U to B&W's new fuel fabrication factory at Lynchburg, Va.

Sinclair Oil to use spent MTR fuel elements as radiation sources in petroleum research. The oil company announced last month that it will be the first to use the powerful gamma radiation from fuel assemblies taken from AEC's materials testing reactor. Sinclair is going to build a $500,000 radiation and isotope lab at Harvey, Ill., near Chicago, where it will study radiation effects on cracking, hydrocracking, hydrogenation, dehydrogenation and isomerization. The fuel elements will be stored in a well under 20 feet of water, and lifted out by remote-control handling apparatus during experiments.

A NUCLEONICS inquiry to AEC about rental charges and mode of application to obtain spent fuel elements brought the reply that prices and arrangements had not yet been decided; that only preliminary discussions had been held with industry to date, and that no commitments had been made. Sinclair says it has a commitment from AEC in the form of a letter saying that the spent fuel elements would be made available when arrangements were worked out.

NAA entering food radiosterilization field. Atomics International division of North American Aviation has begun a one-year study to determine the most practical means of preserving food by radiation sterilization, under a contract with the U. S. Army Quartermaster Corps. The four areas of the study are: reduction of field refrigeration by the use of radiosterilization or pasteurization; improvement in the quality of canned foods; deinfestation of grain and dried solids such as powdered milk, oatmeal, etc.; and irradiation of foods to prevent sprouting. Primary emphasis will be on military economics and logistic feasibility, but possible commercial applications will also be explored. AI will analyze existing methods from an industrial standpoint rather than seeking to develop new ones. Radiation sources being considered for the study are accelerators, radioisotopes, spent reactor fuel elements, direct reactor radiations, and radiation from reactor coolants.

Britain plans to harness spent elements for production. Sir John Cockcroft, head of British atomic research, said in London that "the radioactive waste products from Britain's atom power plants are likely to be used for the industrial manufacture on a large scale of a number of already-existing materials and some entirely new materials when the U. K. power program gets under way." By 1965 more than 2 tons of radioactive "ash" would be produced annually by the power program, he said; one type—Cs^{137}—would alone possess several million curies of radioactivity. Specific projects contemplated include manufacture of polyethylene plastic from ethylene gas simply by exposing it to radiation, thus eliminating complex chemical reactions for making the raw plastic. 100,000 curies of fission products suffice to make 1,000 tons of polyethylene, at a cost for radiation of 1.5 cents. Other plastics such as methacrylate, styrene, and fumarates could be manufactured in this way.

ured by scintillation counters. The readings, analyzed in terms of pulse rate and strength, tell the type and concentration of radioisotopes in the samples (NU, April '55, p. 38) and permit immediate adjustment, if necessary, of the chemical process.

• **Package power economics:** Alco revealed cost data on power generation with the Army Package Power Reactor now building at Ft. Belvoir, Va. Total fuel cost for APPR, Alco said, will not exceed 9½ mills/kwh, using 6 mills/kwh for fuel cost (with U-235 at $25/gm), 2½ mills for fuel fabrication and 1 mill for reprocessing. With labor at 1½ mills/kwh, total operating cost for a semiportable 2,000-kw plant will be about 11 mills/kwh. Fixed charges are reckoned at 5.8 mills/kwh using a 10% rate, an investment of $400/kw, and 80% load factor. Overall costs thus total 16.8 mills/kwh. Alco says costs with a comparable small plant using coal all year round are 14 mills/kwh.

• **Cesium recovery:** A new method for recovering large quantities of Cs^{137}, one of the valuable waste products of reactor operation, was reported by Phillips Petroleum Co., operators for AEC of the Idaho Chemical Processing Plant. The high solubility of cesium compounds makes their direct chemical separation difficult; the new method uses nickel or ferric ferrocyanide as a cesium scavenger; losses are less than 1%. Cs^{137} is a valuable source of radiation for drug sterilization, cancer therapy, radiography, etc.

• **Reactor control:** A General Electric reactor designer predicted a swift disappearance for reactor control rods. "There is a trend in the design of reactors," said Samuel Untermyer, "toward selection of those types which will be inherently self-regulating," responding to any power demands without the need for adjustment of control rods.

• **Teaching simulator:** A 40-lb, 10-in.-high "reactor" that gives students in nuclear engineering the feel of a real one but without radiation hazard and at a cost of a few hundred dollars has been developed at Michigan University. The simulator, a specialized electronic computer, has dials and controls governing position of control rods, coolant flow, ratio of reactor temperature to rate of reaction, and other variables; the student is in full control of the "reactor." If he fails to control it properly, the "reactor" runs away—but with no damage to the simulator.

Reactor News

Cost figures on PWR revealed. At a press background briefing on reactor technology in Washington last month, Adm. H. G. Rickover disclosed that designers of the Shippingport PWR hope to bring down power costs from 52 to 15-mills by the third fuel loading. With the first core, in addition to 15 mills/kwh for fixed charges (including both U. S. and Duquesne contributions), the fuel charge including cost of core-fabrication, zirconium, etc., will come out to 39 mills/kwh, and operating cost to 3 mills/kwh; from this total of 57, 5 mills credit for chemical reprocessing are subtracted. However with the second core, using technological lessons learned and with lowered fuel fabrication costs—also assuming that the plant can be run at 90 Mw instead of its original 60 Mw rating—this arithmetic comes out to 32 mills/kwh; and with the third core, to 15 mills. PWR will be recharged a whole core at a time. The first core is expected to last about 8000 full-power operating hours, or something more than 1½ years; exactly how long is not known because the plant will be used mostly for experimentation in its first year. It is expected to operate at 10% of capacity in the first year, 20% in the second year, 40% in the third, 60% in the fourth, and 80%, or normal, in the fifth. It may be 1965 before the third core is installed. Fuel weight will be 11–12 tons of natural U in the blanket region, 50–60 kgs. of highly-enriched U in the seed region.

AEC pushing OMRE. By the end of the year AEC hopes to have an Organic Moderated Reactor Experiment unit of several Mw in operation, reactor chief W. K. Davis told NUCLEONICS. He said early experiments on this approach surpassed expectations in that the moderator holds up well under radiation and there is not as much film deposited on the fuel elements as had been feared. The prototype will probably be built at Arco. North American Aviation has offered to pay half the cost of building a pilot plant.

Nebraska to use "double barreled" approach. The atomic power reactor project proposed by Consumers Public Power District of Nebraska will employ a "double barreled" approach to the most economical use of atomic energy. Dr. Chauncey Starr, head of the Atomics International division of North American Aviation which is to build the 75,000-kw sodium graphite power plant, said it is hoped the installation would reap the benefits of both heat and radiation to make the most economical and efficient use of atomic energy. The plan is to make available radiation, process heat and steam for industrial users: "Low cost power," he said, " . . . for . . . providing process heat and steam is in great demand by industries whose products are receptive to improvement by radiation."

Industrial research reactor planned in Canada. A $2-million reactor specifically designed for industrial research has been proposed by Isotope Products Ltd. of Oakville and the Pulp and Paper Research Institute; several firms have already agreed to participate, and others are considering the plan. Up to a dozen companies in the rubber, oil, chemical, metal and food industries and the entire Canadian pulp and paper industry would take part. Preliminary design studies will take 9 months and the reactor may be in operation by early 1958. It may produce radioisotopes for participating firms in addition to its research function.

Time held ripe for nuclear gas turbines. A revival of the gas-cooled reactor was forecast in Washington last month at the first unclassified meeting ever held on the subject. The four speakers—T. Jarvis of Ford Instrument Co., J. G. Gallagher of Alco, S. T. Robinson of American Turbine Corp., and C. H. Fox of Glenn L. Martin—said power plants using turbines driven by reactor coolant gas could be made as compact, at least as efficient, and comparable in cost to other types now being designed. Three of the four speakers appeared to prefer the closed cycle to the open cycle gas turbine, although the latter is cheaper. All agreed it was a mistake the have cut short work in this field 10 years ago. Capt. J. J. McMullen of the Maritime Commission predicted the first atomic ship would be gas-turbine powered. A gas-turbine reactor plant may be proposed under the second round of AEC's power demonstration program.

World News

Germany advancing swiftly. New evidence of rapid West German strides came to light at the Cleveland nuclear congress, where it was learned that West Germany had already built three U-refining plants, in Belgium, Spain and Argentina—the last one complete with fuel-fabricating facilities—and is negotiating for a fourth with Yugoslavia and will build a fifth at home; that in addition to the Federal research reactor project in the Ruhr and the Bavarian one at Munich, a ship-building group is going ahead with plans for a third in Hamburg; and that a chemical reprocessing plant may also be built this summer. A number of German representatives of industry and government were in evidence at Cleveland. Meanwhile the West German cabinet in Bonn decided the Federal atomic energy commission would be composed of 25 scientists, industrialists and economists, headed by Minister for Atomic Affairs Franz Josef Strauss.

Calder Hall up-rated. Effective power output rating of Britain's pioneer twin-reactor plant has been raised nearly 30% from original design estimates, from about 50 to 65 Mw. The actual useful power output, including heat for space heating and local power consumption, will be equivalent to 92 Mw. The increased rating is thought to be attributable to higher operating temperatures, and lends credence to official comment that the "primitive" gas-cooled Calder design still has much development potential. A design study is already under way for a reactor of this type directly driving gas turbines, eliminating the not-too-efficient heat exchangers.

Geneva atom show to be repeated. The trade fair held last August in Geneva in conjunction with the U. N. Atoms-for-Peace conference will be repeated in August 1957 in Geneva and every two years or so thereafter, the organizing committee has decided. The "brilliant results" of the first fair were such that exhibitors will receive a 32% refund of rent paid for booths.

Meanwhile in England it was announced that the "Atoms for Britain" exhibit, first shown in Geneva, would be staged again at the British Industries Fair in London from April 23 to May 4.

Reactor for Brazil. The president of Brazil's AEC said the National Research Council would acquire in the U. S. South America's first atomic reactor. To be installed in the university city at São Paulo, the pile will arrive there in August this year and be in operation by October 1957, the official said.

Huge U field found in Sweden. State geologist Dr. Josef Eklund announced discovery of what is claimed to be the world's largest field of uranium, with reserves estimated at 1-million tons. Located in central Sweden near Göteborg, the deposit is alum shale containing 300 gms U per ton. Most is exploitable, but whether economically so has not yet been determined, Dr. Eklund said.

Austria seeks power bilateral. At its 9th session a month ago, Austria's AEC urged the Council of Ministers to instruct Vienna's ambassador in Washington to seek conclusion of a power bilateral. The Commission also set up a "reactor committee" to study which type of reactor would best suit Austrian economic and scientific purposes. Atomic experts in Vienna in and out of government believe it advisable, indeed necessary, to jump over the first step in the application of A-power—a research reactor—and to proceed at once to a power reactor that can also "fulfill economic requirements."

U. K. offers aid to Middle East. Britain has offered to place her experience in peacetime atomic development at the disposal of Baghdad Pact members (Turkey, Iraq, Iran and Pakistan) and to make British scientists and technicians available to those who wish to develop their own sources of nuclear power.

Costs of Indian reactor. The NRX-type reactor that Canada is building for India will cost about $14-million, Prime Minister Nehru told Parliament. Canada is paying half the cost, and is prepared to pay more "if the external costs exceed $7-million." India has undertaken to spend $6.3-million, and if the internal costs run higher will meet the excess out of counterpart funds under the Colombo Plan. The reactor will be set up in Bombay.

Britain and India sign bilateral pact. An agreement for "close cooperation and mutual assistance" in developing peaceful uses of atomic energy was concluded between London and New Delhi. Scientists of the two countries will consult and collaborate on "mutually agreed topics." Announcement in New Delhi of the pact on the heels of the Soviet leaders' visit to India was seen as significant in London.

Sweden makes more reactor news. One month after announcement of the "Adam" and "Eve" reactors—a 75 Mw heating plant and a 100 Mw electric power station (NU, Dec. '55, p. 15)—the Swedish Atomic Energy Company announced plans for four new reactors. The semipublic company, which already has one research reactor, "R-1," operating in Stockholm, and is building a second, "R-2," on the Baltic coast, will build four power units. The first, "R3a," will deliver 90 Mw of heat to a power plant, by 1960; an improved version, "R3b," will furnish 71 Mw heat and 13 Mw current by a year or two later. Both are expected to be competitive with Swedish oil-fired plants. "R-4," a longer-range project, will deliver 75 Mw of electricity, and the last, most ambitious of the four, will generate 300 Mw. This program is independent of Adam and Eve, which are a joint undertaking of the Atomic Energy Company, the State Power Board, and the ASEA company.

Defense against winter at Dounreay. Exceptional measures are being taken by the British Atomic Energy Authority at the reactor test station on the northernmost Scottish coast to ensure that winter weather does not slow building operations. Biggest fear is of frost damage to concrete, and schedules call for pouring some 350 tons daily. As it is vital there be no flaws in it, unused naval hangars are being erected around assembly jobs ordinarily done in the open. Screens of wire net supported by tubular steel scaffolding will protect other operations. Portable steam engines will heat mixing water and stone aggregate to make sure concrete does not chill below the temperatures at which it sets well. Dounreay is the site not only of Britain's fast-neutron breeder reactor, but also of another experimental reactor, designated E-775.

South African U production up. Although production figures are not given for security reasons, an idea of the trend may be gained from some published export statistics. Exports of "prescribed materials under the Atomic Energy Act" (mostly uranium) in 1953 were valued at £3.9 million. During 1954 such exports jumped to £14.8 million, while for the first five months alone of 1955 the value was placed at £9.9 million—more than double the value in the same period in 1954. When U resources are fully developed it is estimated annual production value will reach £40 million.

ROUNDUP

News in Brief

Competitive bidding for uranium deposit leases. AEC will institute a new system of leasing for exploitation of its reserve uranium deposits. However extensive leasing of AEC-controlled lands is not contemplated because production from privately-owned properties is still high. The competitive bidding system will replace selection of lessees by AEC.

Nuclear training for engineering teachers. A summer institute on nuclear engineering for engineering college faculty members will be started at Argonne this summer, co-sponsored by AEC, the National Science Foundation and the American Society for Engineering Education. 60 teachers will take the 2-month course.

Forum sponsors insurance study. A $50,000 research project covering problems of public liability in the atomic energy field has been placed with the Legislative Drafting Research Fund of Columbia Law School by the Atomic Industrial Forum. A preliminary report is due March 1 and the study is to be completed within a year. Columbia Law Professors John M. Kernochan and John G. Palfrey will supervise the research.

AEC enlarges international unit. The AEC's Office of International Affairs has been upgraded to division status. John A. Hall continues to head the unit. Its responsibilities include the bilateral program, the proposed International Atomic Energy Agency, and liaison with State Dept. and the U. N. on atomic energy matters.

Yale buys accelerator. A 1-Mev Van de Graaff has been ordered by Yale from High Voltage Engineering Corp. It will be used in fundamental radiobiological studies aimed at determining the structure and function of cell components.

New U strike in Arizona. Described as one of the largest pitchblende discoveries to be made in this country, an ore body located 1300 feet down the slope from the south rim of the Grand Canyon is estimated to contain between 100,000 and 300,000 tons of marketable ore, making it one of the 25 biggest in the U. S. Samples from the strike, on the "Orphan" claim, assay as high as 3.13% UO_3. Total depth of the vertical "stovepipe" formation is still unknown, but at least 217 feet. The Orphan claim is on the only privately-owned land within Grand Canyon National Park. Mining operations will begin in spring.

Big year for small company. Atomic Instrument Co. expects 1955 shipments to top the million-dollar-mark for the first time in its history. Orders for the first 11 months of the year totaled $1,061,905, a 24% increase over the corresponding period in 1954. The company plans an expansion of its production facilities.

Radiomedicine course offered. Queens General Hospital, Jamaica, L. I., in cooperation with AEC, will offer a four months' course in the medical uses of radioactive isotopes beginning Feb. 14.

An LMFR for Pacific Northwest? The Washington State Power Commission is considering a bid to AEC for a 30-Mw LMFR power plant. The $15-million reactor would use a U-Bi slurry at 2600 degrees F.

More Be for AEC. The Commission will this month invite private industry to submit bids on supplying 100,000 pounds of reactor-grade beryllium annually over a 5-year period. Three months will be allowed to prepare proposals. AEC requirements are currently met from production of a Commission-owned plant at Luckey, Ohio, operated for AEC by Brush Beryllium Co.; this will be placed on stand-by status if private industry comes up with acceptable proposals.

BNL reactor declassified. Brookhaven's big graphite-moderated research reactor, critical since August 1950, began operation last month as a declassified facility. Previously its west face had been declassified and opened to non-cleared scientists in 1951. The action opens also the medical, biological and engineering facilities on top of the reactor and the short-lived isotope production facilities on the north face. A total of about 70 simultaneous experiments can be supported by the reactor.

Biggest nuclear microscope in use. Stanford U. physicists have coupled their 220-foot electron linear accelerator to a 55-ton, 16-ft-high magnetic spectrometer to make the biggest "nuclear microscope" ever built. It can measure subnuclear particles with a sensitivity of 4×10^{-13} in. Prof. Robert Hofstadter, directing research with the machine, describes it as "an overgrown electron microscope," making nuclear particles "look" about 100,000 times bigger by shooting electrons of as high as 550-million, instead of 50,000 to 100,000, volts through the target. The Stanford machine makes no photographs, but counts and measures the precise energy losses and angles of deflection of target-piercing electrons. From this, physicists can reconstruct the size and shape of nucleons. The Stanford group hopes the instrument will permit detailed examination of protons.

Staggering energy demand forecast. By 1964 the U. S. will need a "staggering" 1,040-billion kwh of electricity, according to O. B. Falls Jr., marketing manager of General Electric's atomic power equipment dept. "We will have to more than double our generating capacity within the next 10 years," he said. Latest GE studies show that by 1970 14%, and by 1980 65%, of all additions to generating capacity will be atomic.

Combustion comes to Connecticut. A 530-acre site at Windsor, Conn., has been bought by Combustion Engineering, Inc., to house a nuclear engineering and development center. The $5-million center, scheduled to be in operation by the end of the year, will include facilities for the complete design and development of nuclear power reactors, for the construction of reactor cores, and for the manufacture of fuel elements. A large two-story engineering and administrative building, a critical facility for core experiments, a hot lab, a fuel element fabrication plant and metallurgical, chemical and physical testing labs will be built. Stone & Webster are architect-engineers. Only "light" components will be built at Windsor; "heavy" items such as reactor pressure vessels will continue to be fabricated at the Chattanooga, Tenn., plant. Personnel of the company's nuclear power and reactor development divisions will be transferred from New York to Windsor when the plant is ready for occupancy.

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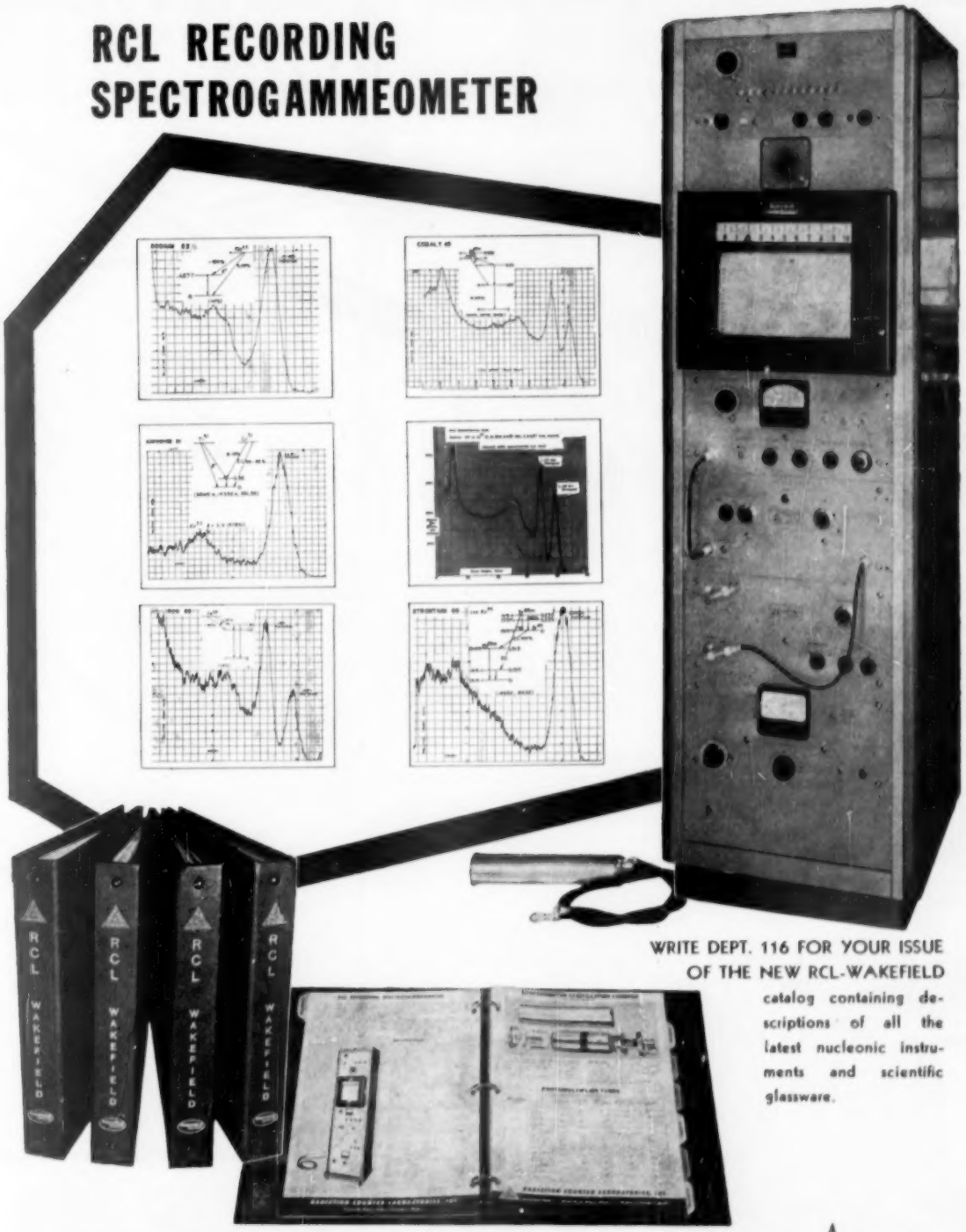

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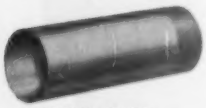

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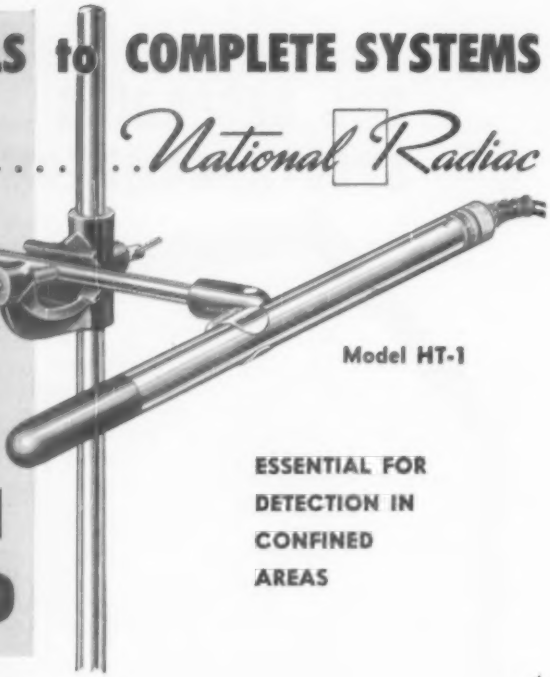

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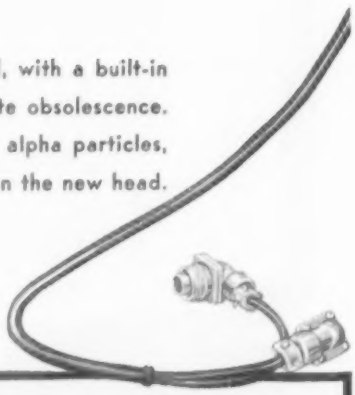

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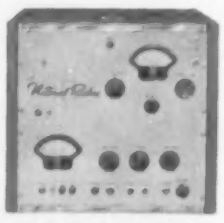

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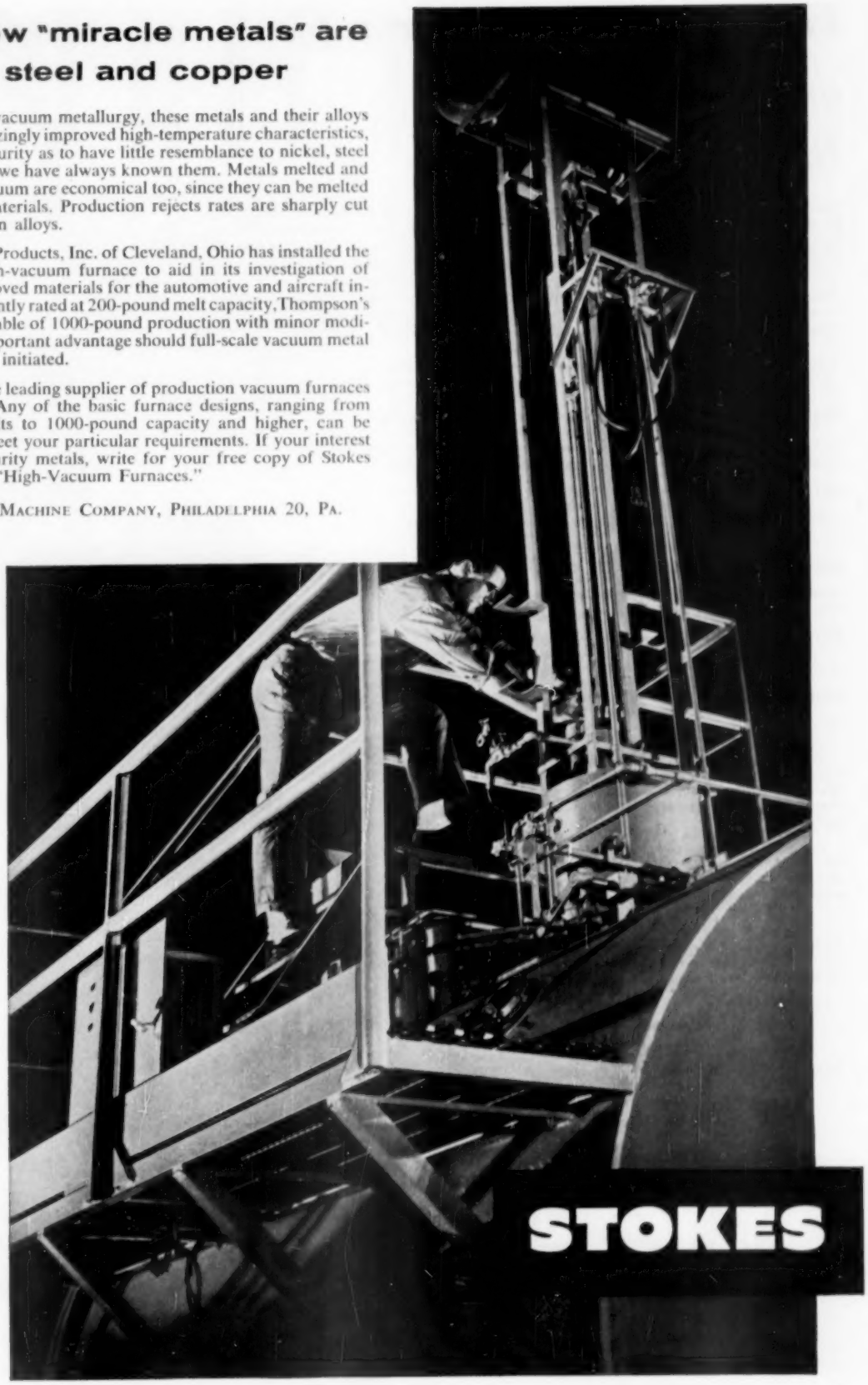

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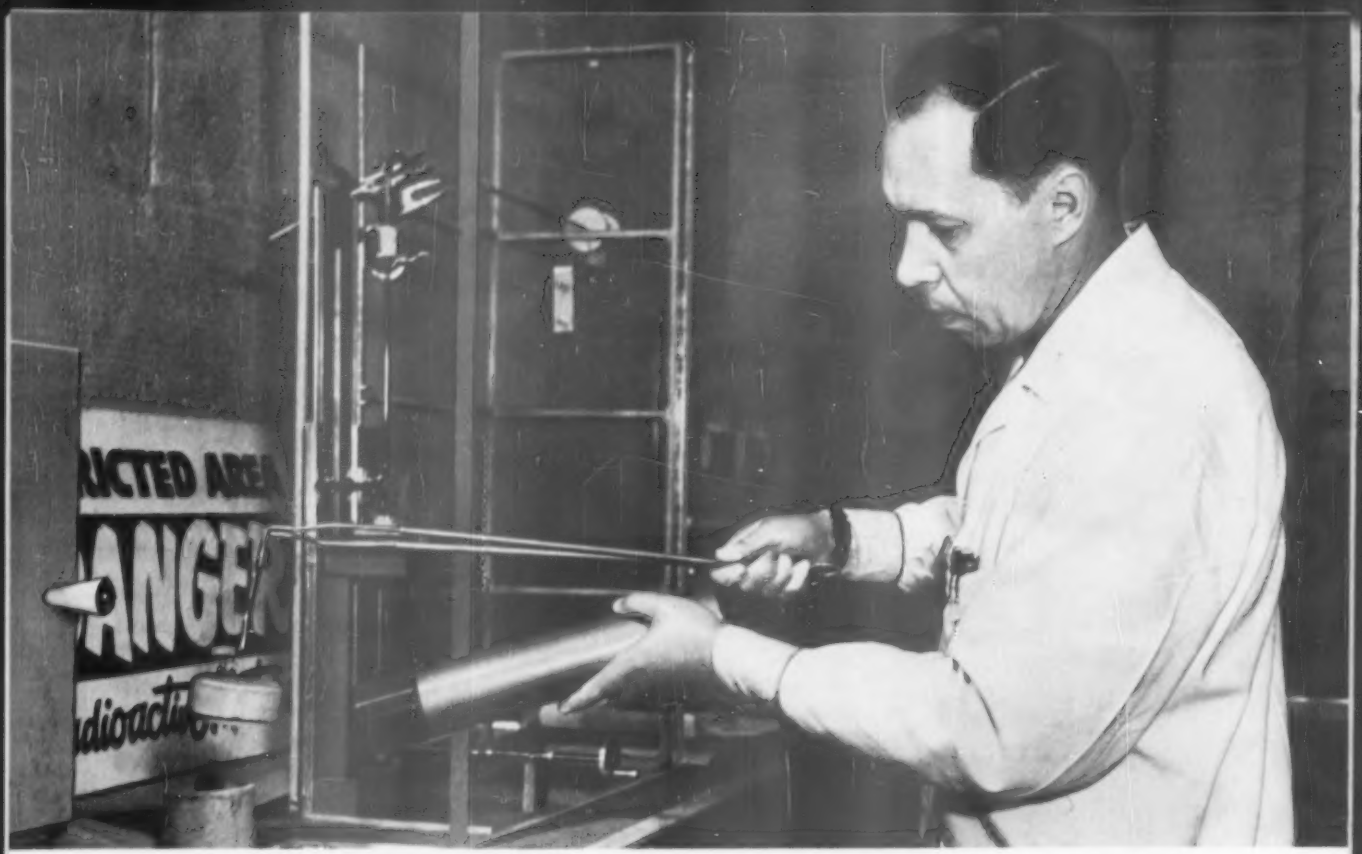

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GENERAL ELECTRIC

Predicting Reactor Temperature Excursions by Extrapolating Borax Data

Borax data on temperature excursions are extrapolated for use in predicting performance of the U. of Michigan research reactor. The generalization, which is for the initially subcooled condition, agrees well with the limited data for this case

By WILLIAM K. LUCKOW and LAWRENCE C. WIDDOES*
Phoenix Project
University of Michigan
Ann Arbor, Michigan

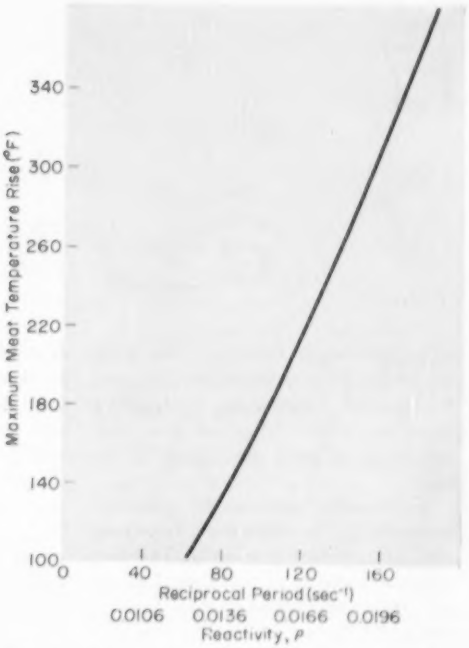

FIG. 1. Borax data—how the maximum fuel-plate temperature rises for various stable reactor periods. At the start of the excursions, the water was 200° F and boiling

PREDICTION of a reactor's transient behavior, the mechanism of termination of temperature and power excursions, and the effects of these on the reactor and its surroundings comprises an important part of every safety analysis. This type of survey was required for the University of Michigan swimming-pool-type research reactor (*1*).

Such a study is difficult and subject to uncertainties. But recent experimental investigations of a heterogeneous water-cooled and water-moderated system have put transient analyses of this and similar systems on a more substantial basis (*2, 3*). These so-called "Borax" experiments were performed during the summers of 1953 and 1954 by personnel of the Argonne National Laboratory on lattices very similar to the swimming-pool-type reactor being constructed at the University of Michigan and other educational and industrial installations. The experiments were designed to develop data on the nature and limitations of power excursions in reactors that are cooled, moderated, and reflected by water.

During the fall of 1953 the University of Michigan Memorial-Phoenix Project analyzed the data available from the 1953 tests and extrapolated the data to predict the transient behavior of a swimming-pool-type research reactor. The results are summarized here (*4*).

Data Extrapolation

Two types of preliminary information on temperature transients were available when the original study was undertaken. First, extensive data on temperature excursions from the saturated condition as a function of stable reactor period were taken. These are shown in Fig. 1. Temperature measurements were made in the uranium-aluminum-alloy "meat" of a plate of a special MTR-type fuel element (140 gm U^{235}/element loading). This element was located in the center of the core at one of the two points of highest

* PRESENT ADDRESS: Internuclear Corp., 7 N. Brentwood, Clayton, Mo.

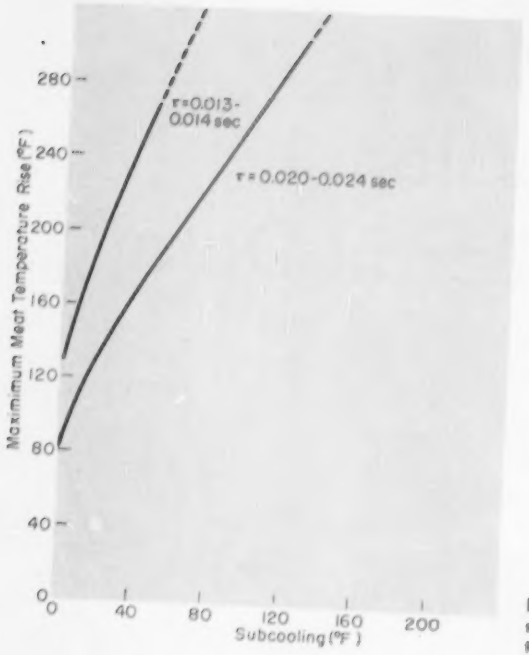

FIG. 2. Borax data—how various degrees of subcooling affect the rise in fuel-plate temperature for two ranges of stable reactor period

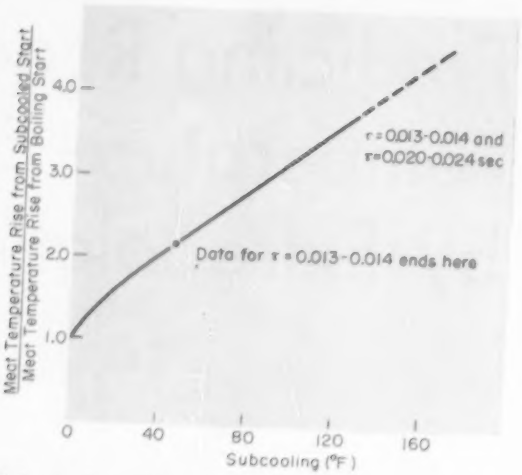

FIG. 3. Generalized effect of subcooling on fuel-plate temperature rise

measured power density. The data are for the plate that consistently gave the highest temperature readings of those recorded. Thus, it was presumed to be the hottest plate in the core.

Stable-period data can be converted to reactivity by well known equations if an independent value of the effective neutron lifetime is available. When this study was undertaken, a value of 7.6×10^{-5} sec was assumed for the system and period information was expressed in terms of reactivity on this basis. A detailed analysis of the 1953 Borax experiments arrived at 6.5×10^{-5} sec as a better value. The larger value of the effective lifetime used underestimates the severity of the excursion produced by a given amount of reactivity.

The wide application of the data of Fig. 1 to research reactors is hindered by the fact that no research reactor of this type operates and none are contemplated to operate at saturation temperatures. Rather, the subcooled* condition is more characteristic of the operating conditions of swimming-pool research reactors.

The second type of experimental information available after the 1953 tests, the comparatively meager amount of data taken at subcooled conditions, is presented in Fig. 2 (5). The more recent 1954 tests extended this information, but only at the condition of 120° F subcooling. Since some swimming-pool-type installations, the one at the University of Michigan in particular, propose to operate at degrees of subcooling intermediate to or beyond areas of experimental investigation, an extrapolation or generalization remains a valuable tool in spite of the accumulation of experimental data.

Approach

An evaluation of the extensive data taken at the saturated condition and the comparatively limited number of tests conducted under subcooled conditions pointed to the desirability of developing a method of extrapolating to other conditions.

The complexity and probable interaction of the mechanisms involved were considered, and it was concluded that an elementary correlative approach probably has as high a probability of success as a more penetrating theoretical analysis, though presenting no insight into the detailed mechanisms. Such a simple approach was taken.

The temperature excursion experienced on the step insertion of a given amount of reactivity was postulated to be a function of initial subcooling, s, and the reactivity, ρ, only. Furthermore, this function was assumed separable into functions of reactivity and subcooling alone, or symbolically

$$\Delta T(s,\rho) = S(s)\, R(\rho)$$

If this relation is valid, for a fixed value of reactivity the ratio of two temperature excursions should be a function only of the ratio of the subcooling functions. In particular, if one of the excursions is made at the saturated or zero degrees of subcooling condition, the ratio becomes

$$\frac{\Delta T(s,\rho_1)}{\Delta T(0,\rho_1)} = \frac{S(s)R(\rho_1)}{S(0)\,R(\rho_1)} = \frac{S(s)}{S(0)} = \text{constant} \times S(s)$$

Such a generalization of the data of Figs. 1 and 2 is shown in Fig. 3. The data for the two periods fell very nearly on the same curve though the amount of data available for correlation was quite limited. A similar correlation of the data on the total energy of excursions from saturated and subcooled conditions also can be made.

The following steps then were taken to make use of the generalized plot in the prediction of the temperature excursion from a given subcooled condition resulting from the step introduction of a given amount of reactivity: (a) the equivalent temperature rise from the saturated condition for the given amount of reactivity was read from Fig. 1; (b) the ratio of the tem-

* "Subcooling" is defined as the saturation temperature minus the initial reactor temperature.

perature rise from the given subcooled condition to the temperature rise from the saturated condition was taken from Fig. 3; (c) the temperature rise from the saturated condition taken from Fig. 1 then was multiplied by the ratio read from Fig. 3 to give the temperature excursion predicted for the subcooled condition.

Figure 4 depicts the maximum fuel-element temperatures expected on the introduction of various reactivities at different degrees of subcooling. It was arrived at by this procedure. The particular temperature conditions shown are those peculiar to the University of Michigan reactor; reactivities were calculated from the assumed neutron lifetime of 7.6×10^{-5} sec. On the basis of Fig. 4, melting of the meat of the hottest fuel plate in the Michigan reactor was predicted upon the introduction of 1.8% reactivity at 80° F (156° F subcooling). This condition was taken to represent fuel-element failure even though it was recognized that a temperature distribution would exist across the fuel plate.

It subsequently was proposed to AEC's advisory committee on reactor safeguards that the excess reactivity in the Michigan reactor at any given time be limited to 1.6% so as to assure absolute safety. A modification of this proposal was among the operating restrictions placed upon the University by the Commission.

Agreement with data. The success of the generalized correlation approach can be measured in terms of the agreement between predicted and measured temperature excursions made at 120° F of subcooling during the 1954 Borax tests. Over the range of reciprocal periods studied, 20–50 sec^{-1}, the predicted temperature excursions averaged within 20% of the maximum plate temperatures measured. Total energies of excursions predicted by a method identical to that reported here for temperature excursions deviated by a maximum of 14% from those measured over the range of 20–60 sec^{-1} reciprocal period. In general, such calculations are rather insensitive to inaccuracies in the generalized plot.

Forced Circulation

In addition to intermediate subcooling, two other operating conditions whose effects have not been experimentally determined are anticipated for use in the Michigan reactor. These are: (a) forced circulation; and (b) graphite reflection. Their effects on transient behavior can be predicted only qualitatively at this time.

Forced circulation velocities of 1–2 ft/sec are planned. Since the duration of a typical excursion is about 100 msec, and since large pressures are generated during excursions, the motion of the water is not expected to have an appreciable effect. But the increase of the heat-transfer coefficient over that under stagnant or natural circulation conditions would facilitate heat dissipation to the water. Thus, depending on the mechanism of steam formation, it might decrease the total energy generation necessary to vaporize the amount of water needed to shut the reactor down.

Graphite Reflector

Replacing the water reflector with the more effective graphite has several effects. The critical mass, and thus the number of fuel elements, is reduced. This increases the power density per element and serves to accentuate forced-circulation effects because of the reduction in flow area. Second, the flux and power distributions are flattened, which tends to take the power dissipation burden off the center elements and redistribute it more evenly. Third, the effective neutron lifetime is lengthened due to the increased number of neutrons reflected back into the lattice. This reduces the severity of an excursion by increasing the e-folding time of the transient. Finally, the increased reflective power of the graphite tends to decrease the effectiveness of voids (steam bubbles) in reducing the reactivity of the lattice. This last effect increases the severity of the transient resulting from a given increase in reactivity.

On balance, the changes in transient behavior attributable to forced circulation and graphite reflection are expected to have the net effect of reducing the violence of an excursion.

* * *

The contributions of Argonne National Laboratory, whose personnel developed the data on which this article is based, and Russell B. Mesler, who aided the authors in their analysis, are gratefully acknowledged.

BIBLIOGRAPHY

1. W. K. Luckow, L. C. Widdoes, NUCLEONICS **13**, No. 6, 104 (1955)
2. J. R. Dietrich, Determination of the self-regulation and safety of operating water-moderated reactors (International Conference on Peaceful Uses of Atomic Energy, Geneva, 1955)
3. NUCLEONICS **13**, No. 9, 40, (1955)
4. W. K. Luckow, R. B. Mesler, L. C. Widdoes, MMPP-75-1 (1953)
5. J. R. Dietrich, Argonne National Laboratory, private communication

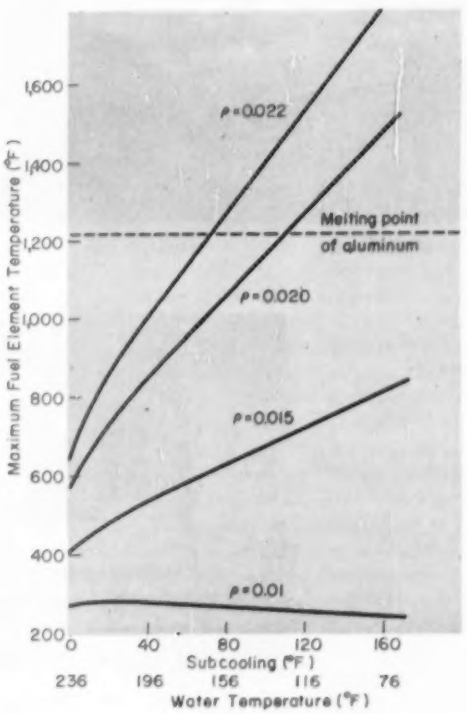

FIG. 4. Estimated maximum fuel temperature as result of excursions with various excess reactivities

The Los Alamos Human Counter

Take 140 gallons of liquid scintillator, scan it with 108 photomultipliers, shield it with 20 tons of lead . . . then you've got the essentials of a counter that will determine the gamma activity of body potassium to 5% in 100 seconds

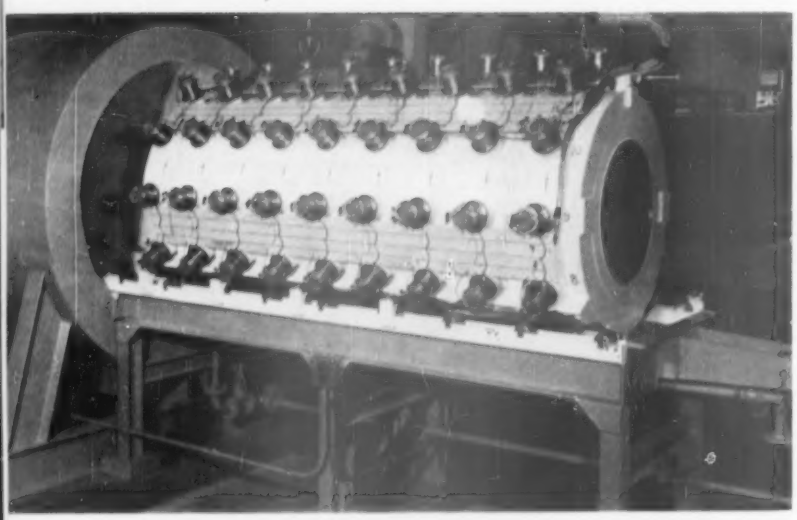

FIG. 1. Counter outside of lead shield

By ERNEST C. ANDERSON, ROBERT L. SCHUCH, JAMES D. PERRINGS, and WRIGHT H. LANGHAM
Los Alamos Scientific Laboratory
University of California
Los Alamos, New Mexico

FIG. 2. General view of counter showing lead shield, loading trough, and subject about to lie down in sling that will carry him into counter

THE PROSPECTIVE GREAT INCREASE in the use of nuclear reactors and radiation sources will increase the need for rapid and highly sensitive methods of monitoring for radioactivity. As more and more people are potentially exposed to contamination, genetic considerations indicate lower levels for the maximum permissible exposure. There appears to be a growing need of an instrument capable of detecting radioactivity in human beings and in foodstuffs at levels well below the recommended maximum permissible concentrations (*1*).

The Human Counter was designed to meet these requirements for gamma-emitting nuclides. The sensitivity of the detector is 5×10^{-10} c for a nuclide emitting one gamma ray per disintegration and its sample capacity is 300 lbs. For large samples, concentrations of gamma emitters as low as 3×10^{-12} c/kg can be detected. The sensitivity is such that the natural K^{40} content of the body (about 10^{-8} gamma-ray curies) can be measured to a precision of 5 percent in two minutes of counting time.

Description

The Los Alamos Human Counter is essentially an enlarged and improved version of the 4π gamma-ray detector ("dog counter") previously described (*2*), and of the original human counter which was a temporary modification of a neutrino detector (*3*). It consists of a cylindrical tank 72 in. in length by 30 in. in diameter, with an 18-in. diameter thin-walled tube (0.019-in. stainless steel) running down the axis (Fig. 1). The annular space between the tube and tank wall is filled with the scintillation solution 4 gm/l terphenyl and 0.1 gm/l 1,4-di[2-(5-phenyloxazolyl)]-benzene (POPOP) dissolved in reagent-grade toluene. The capacity of the detector is 140 gal (about 1,000 lb). The inside of the tank is painted with a special reflective coating of anatase TiO_2 in an epoxy resin that withstands the attack of the solution.*

Scintillations are detected by 108 photomultiplier tubes (DuMont 6292) inserted through the outer wall of the tank in 12 rows of 9 tubes each. The central cavity accommodates the subject or the sample within the sensitive shell so that the effective counting angle is nearly 4π and the counting efficiency can be made nearly independent of source position. The detector is enclosed in a 5-in.-thick 20-ton lead shield. Figure 1 shows the detector rolled out of the shield for servicing. It is mounted on heavy rails and ball-bearing rollers, so that one man can easily move it. Figure 2 shows how the subject is put into the detector. A metal trough is placed on the track on which the tank rolls so that it forms an extension of the central cavity. The subject lies down in a canvas sling which is drawn from the trough into the detector by means of a windlass.

Tubes are mounted as in the K-9 dog counter (*2*). Each tube views the solution through a glass window so that tubes can be changed without draining the tank. The window is cemented into the end of a steel tube with epon resin. An O-ring seal provides a tight joint between this tube and another welded into the tank wall.

Figure 3 is a schematic diagram of the method of wiring the photomultipliers. The bleeder circuits, one of which is shown, are conventional using 470-k resistors between all stages. The last three dynodes are by-passed by 5,000-$\mu\mu$f capacitors for stability at high rates. The shield is kept halfway between the cathode and first-dynode potentials. The tubes are balanced by means of an additional resistor R in series with the bleeder string. This resistor adjusts the voltage drop per stage so that the output pulses of all tubes are equal for events of the same energy. An unequal voltage drop results between the anodes and tenth dynode, but the tube characteristic is independent of this voltage over a very wide range (*4*).

To eliminate paralleled anode load resistors and output capacitors, the anodes are tied together at the high-voltage-supply potential. (A positive supply is used to prevent spurious pulses which arise through the glass envelope when the cathode is operated at a high negative potential.) Provision is made for dividing the tubes into two banks, a convenience in testing and a necessity when counting very soft gammas. Coincidences can then be observed between the two banks to eliminate tube noise. Tube noise and spurious after-pulses are negligible for events with energies above 1 Mev, so that single-channel operation is used in this case. The tubes in a given row are alternated between the two channels. Each channel has a single 10-Meg load resistor for its entire 54 tubes and one output capacitor of 500-$\mu\mu$f capacity.

The electronic circuits used to amplify, analyze and record the pulses are conventional (*5*). The energy resolution of the detector is sufficient to permit considerable background reduction by proper pulse-height selection, so that independently variable upper and lower discriminators are used in each channel. In addition to the scaler used for actual measurements, a precision rate meter driving a strip-chart recorder is in operation at all times. While the rate meter is not accurate enough for a precise activity determination (which requires a precision of 2 cps in 400), it can be used to detect nonstatistical fluctuations in the average rate due to electrical interference, slow drifts in the electronics, etc. In practice, the apparatus has been shown to be stable to 0.5% of the background rate over periods of several hours. Because of the high counting rates (background 400 cps, average person 50 cps of K^{40}), statistical accuracy is obtained in very short times. A 100-sec count on the average subject will determine his activity to a statistical precision of better than 5%, so that long-term stability is not an essential requirement.

The table on this page shows the

Background Determinations

Time of day	*Background (cps)*	*Deviation from average*
12:10	447.7 ± 2.0	$+2.0\sigma$
12:50	443.3	−0.2
	438.8	−2.5
13:20	441.4	−1.2
	445.2	+0.7
	444.3	+0.2
15:20	439.5	−2.1
18:30	445.2	+0.7
	446.2	+1.2
	445.8	+1.0
	444.9	+0.6
	450.6	(+3.4)
20:30	449.1	(+2.7)
21:00	452.3	(+4.2)

Average: 443.8 (excluding last three values)

* Glidden's Zopaque SD in Shell Chemicals Epon Formulation XA-200.

results of 14 determinations of background (100-sec counts) made during the course of a single day's operation during which time 65 subjects were measured. The last three determinations, while apparently self-consistent, are significantly higher than the previous sequence. The average of the first 11 measurements, extending over a period of six hours, is 443.8 cps. As can be seen from the last column of the table, the scatter of the individual measurements around this average appears to be statistical.

A more detailed description of the mechanical features of the counter design will be found in the report LA-1717 (*5*).

Body Potassium Content

The Human Counter has been used to make a preliminary study of the variation of the potassium content of people as a function of their body weight and age. Potassium is naturally radioactive, the isotope responsible for the activity being K^{40}, abundance 0.01%, half-life 1.25×10^9 yr (*6*). The decay is to Ca^{40} by emission of a 1.4-Mev beta particle or to A^{40} by electron capture. In the latter branch of the decay scheme, a 1.45-Mev gamma ray is emitted. It is this gamma ray which is used to measure the potassium. The gamma emission rate of ordinary potassium is 2.96 dps/gm (*6*). Since the average person contains about 150 gm of potassium (*7*), the gamma emission rate from this source is expected to be about 450 dps. At 10% efficiency, one would expect 45 cps from the potassium in the average human body.

Since potassium is largely concentrated in muscle, very little being found in bone and fat, potassium content might be expected to vary appreciably with body type. Measurements were therefore made on a group of people of both sexes whose ages varied from 4 years to 75 years. Most of the group had no occupational connection with radioactive materials. The group was "random" to the extent that it represented visitors to the Health Research Laboratory during the July, 1955 open house at Los Alamos Scientific Laboratory.

Two 100-sec counts were made on each subject and backgrounds were measured periodically throughout the day. The ratemeter trace was used as a monitor against short-term background drift. The gross counting rate observed from the subjects was usually slightly below the background with the detector empty because of soft radiation entering the open end of the shield and absorbed by the subject. (This end will be closed with a 2-in. lead door to eliminate this effect.) Correction was made for background depression using the results of the measurement of a series of sugar phantoms of various weights. The precision of the determinations is believed to be ±6 cps or better in all cases.

The results of this study are shown in Fig. 4. In spite of the considerable scatter of the data, certain trends

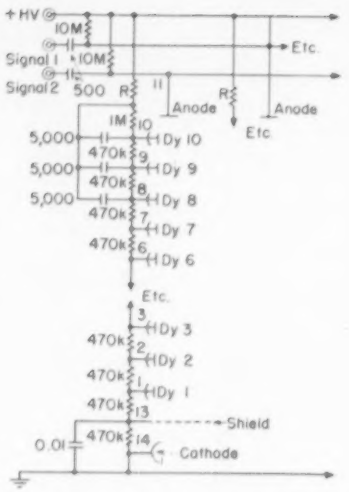

FIG. 3. Schematic of photomultiplier circuit

are evident. The group of points in the lower left portion of the graph represent children. The scatter here is probably within the statistical precision of the measurement, and may reflect a certain uniformity of body build among these subjects. There is no significant difference between girls and boys. The adult points seem to scatter downwards from the extrapolated line passing through the points for children, presumably representing the addition of fat to the basic frame. Note that the average activity of the women is significantly below that of the men and that the range of variation among adults (more than a factor of 2)

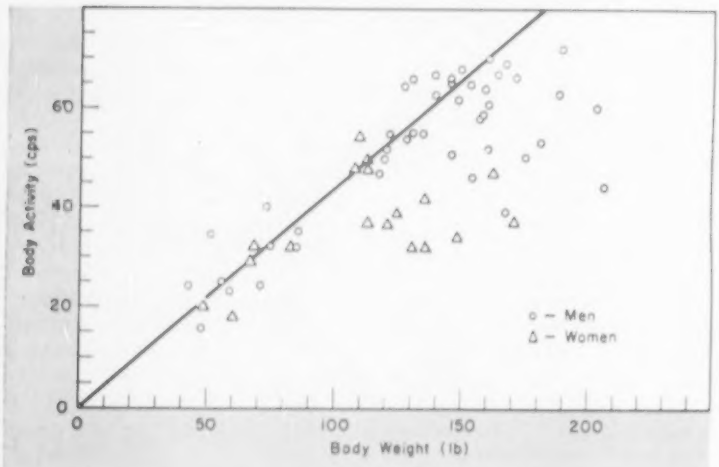

FIG. 4. Gamma activity of human subjects as function of body weight

Assaying Reactor Accidents

The Human Counter could be used to determine the body dose resulting from overexposure to thermal neutrons. The neutrons activate body sodium to an extent proportional to the dose received. It is estimated that an acute exposure to thermal neutrons, resulting in a dose of 0.3 rep, would produce enough Na^{24} activity to be measured with this detector.

This application, which could be of interest in nuclear power plants, was pointed out to us by Dr. Austin Brues.

is definitely larger than experimental error. The range seems in agreement with previous results (*8–10*). This analysis of the nature of the variations is of course a very superficial one, and a further study of the correlation of potassium activity with other parameters of the body is planned. (Deviations from the norm for natural potassium content of the body arise in certain diseases, as for example, muscular dystrophy. See the discussion at right of jobs for the human counter.)

The counting efficiency of KCl in a sugar phantom was found to be 8.7%, compared with 10% for KCl alone. This indicates 13% self-absorption for the average human. The average potassium content of men, 61 cps, therefore corresponds to about 200 gm of potassium and the women's average, 51 cps, indicates 170 gm. These numbers are larger than the value of 150 g given by Shohl (7) and the value of 140 g recommended by the International Commission on Radiological Protection (*11*); but in view of the large scatter, the difference is of little significance.

* * *

We are deeply indebted to the Los Alamos shop department for their collaboration in the design and construction. In particular, B. H. Pohlmann and R. I. Howes did an excellent job of solving the many mechanical problems involved. The whole project would have been impossible without the support and encouragement of Darol Froman. F. N. Hayes prepared the scintillation solution and J. H. Larkins assisted in the design. The work was done under the auspices of the U. S. Atomic Energy Commission.

BIBLIOGRAPHY

1. Handbook 52, National Bureau of Standards, Washington, D. C., 1953
2. M. A. Van Dilla, R. L. Schuch, E. C. Anderson, NUCLEONICS **12**, No. 9, 22 (1954)
3. C. L. Cowan, F. Reines, F. B. Harrison, E. C. Anderson, F. N. Hayes, *Phys. Rev.* **90**, 493 (1953)
4. B. R. Linden, NUCLEONICS **11**, No. 9, 30 (1953)
5. E. C. Anderson, R. L. Schuch, J. D. Perrings, LA-1717, (1955)
6. A. D. Suttle, Jr., W. F. Libby, *Anal. Chem.* **27**, 921 (1955)
7. A. T. Shohl, "Mineral Metabolism," (Reinhold Publishing Corp., New York, 1939)
8. I. D. P. Wootton, M. D. Milne, E. J. King, *Ann. Rev. Biochem.* **23**, 441 (1954)
9. R. M. Sievert, *Ark. f. Fysik* **3**, 337 (1951)
10. F. Reines, *et al.*, *Nature* **172**, 521 (1953)
11. *Brit. J. Radiology, Supplement 6*, Recommendations of the International Commission on Radiological Protection (1955)
12. Private communication, M. A. Van Dilla, Department of Radiobiology, University of Utah
13. A. F. Stehney, W. P. Norris, H. F. Lucas, W. H. Johnston, *Am. J. Roentgenol.* **73**, 774 (1955)
14. L. D. Marinelli, C. E. Miller, P. F. Gustafson, R. E. Rowland, *Am. J. Roentgenol.* **73**, 661 (1955)
15. L. D. Marinelli, C. E. Miller, R. E. Rowland, J. E. Rose, *Radiology* **64**, 116 (1955)

Jobs for the Human Counter

These five major research programs are planned for the Human Counter:

1. Monitoring of Personnel and Foodstuffs

The extreme sensitivity of the instrument should make it valuable for the study of possible gamma contamination from nuclear reactors, uranium mining operations, and bomb fallout. The fact that gamma activity can be detected rapidly and easily at levels below the maximum permissible concentrations means that contamination can be detected before it reaches dangerous levels, in time for remedial measures to be taken. For the monitoring of foodstuffs, forages, etc., the sensitivity, as mentioned above, is 5×10^{-10} c in samples up to 300 lb. in weight. For the monitoring of personnel, uncertainty in the natural K^{40} level is the limiting factor. If this uncertainty is 50% (a pessimistic estimate), the limit of detection is 5% of the permissible amount for Ra^{226} in equilibrium with its daughters, 3% for I^{131}, and 0.01% for Na^{24} and Mo^{99}. If the K^{40} can be predicted to 5% (by an isotope dilution measurement with K^{42} or by a correlation such as discussed below), the sensitivity is tenfold greater. This sensitivity is attainable with counting times of two minutes per sample.

2. Studies of Body Potassium Content

The reasons for the large variation of potassium from person to person are of considerable intrinsic interest from the viewpoint of physiological chemistry. Correlation of potassium content with body type, total body water, lean body weight, or similar parameters would provide a useful method of calculating the "normal" potassium value for an individual. An independent method of estimating body potassium to 5% accuracy would permit the ten-fold increase in sensitivity to other gamma emitters mentioned in the previous section.

Deviations from the norm for natural potassium content of the body are of clinical interest in certain diseases, as for example, muscular dystrophy.

3. Human Retention of Gamma-Emitting Fission Products

The sensitivity of the instrument is such as to permit these measurements to be made on human volunteers with amounts of material far below the permissible level. In conjunction with small animal counters similar to the Human Counter, a series of fission-product retention measurements is planned using a number of different species including mice, rats, dogs, monkeys, and men. Such a series should aid in the interpretation of animal retention studies and their extrapolation to man.

4. Counting Beta Emitters by Bremsstrahlung

Van Dilla, using the "dog counter" at the University of Utah, has measured large amounts of Sr^{89} in the dog by means of the bremsstrahlung (*12*). Attempts will be made to extend downward the energy range of radiations that can be detected, in the hope of obtaining better efficiency for the bremsstrahlung. The detection of bremsstrahlung will make possible measurements of such important fission products as the strontium isotopes. A very rough theoretical estimate indicates that it may be possible to reach at least the maximum permissible level of Sr^{90}.

5. Natural Body Gamma Activities

Radium studies, such as those being made at the Argonne National Laboratory (*13*), are of considerable interest because of their bearing on the fundamental problem of the maximum permissible radiation level for man. The success of the method in this direction will depend on the establishment of an independent method for accurate potassium measurement or on the development of a coincidence technique to distinguish radium and potassium. The energy discrimination of the instrument appears to be inadequate to separate the two profitably. The limit is 5×10^{-9} c of (equilibrium) Ra if potassium is not independently estimated, or 5×10^{-10} c if the potassium is known to 5%, assuming 2 min of counting time per subject. The Argonne NaI crystal counter (*14, 15*) has a reported sensitivity of 3×10^{-10} c of Ra (equilibrium ?) for 2 hr of counting time and does not suffer from K^{40} interference.

Examining Irradiated Fuels Under Water

128 slugs per 8-hr shift can be studied for radiation effects at this underwater facility. Three items—primary inspection station, slug cleaner, and dejacketer—are described. Output is high and capital cost low, compared to hot-cell operation

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IRRADIATED FUEL ELEMENTS are examined in detail at a new underwater laboratory. Many normal metallurgical tests are done under 12 feet of water. The fuel elements, called slugs, are uranium metal in an aluminum can. This article discusses three pieces of equipment used: (*a*) the primary inspection station; the first stop in the examining process; (*b*) the cleaner, where the slugs are cleaned; and (*c*) the dejacketer, where the aluminum can is removed from the uranium before further testing.

Rather than handling the radioactive material behind a shielding wall using intricate mechanical devices and periscopes or high-density glass windows, underwater handling using more-or-less conventional tools with extended controls was chosen. Both capital costs and manpower requirements are lower using underwater inspection (see right). Figure 1 shows the examination basins.

The facility is designed to examine 128 slugs per 8-hour shift in Basins I, II, and III, and 32/day in Basin IV.

Slug Flow Path

Slugs are handled in the cartridge (Fig. 2). A monorail-supported dolly operates integrally with the cartridge. The dolly presents any of the 16 slugs carried to each testing device and is used to transport the cartridge from station to station. The cartridge method of transferring is used to ensure slug identification. Each pocket of the cartridge is numbered and recorded opposite the slug number because processing obliterates any slug marking.

Basin I (see cover) is the first and last step in the examination. Slugs accepted for examination at the primary inspection station are transported to Basin II where they are cleaned, weighed, measured, weaseled (a term used for measuring radiation level) and photographed. Certain selected slugs are examined visually in Basin III using a 45×-magnification periscope.

Basin IV is used for examining bare slugs. The slugs are first decapped (end caps removed), to aid in dejacketing; dejacketed; average grain size determined ultrasonically; slugs measured; fractured; photographed; and packaged in cans.

The Case for Underwater Handling

Capital costs of the installed facilities compared to a hot cell of equivalent complexity are not available, but they are believed to be much less for underwater operations. Hot cells need manipulators, shielding windows, ventilating equipment, and glove ports. Further there is a possibility of spreading contamination, with consequent cleanup costs.

But manpower is the real criterion, rather than capital cost.

The underwater installation can be operated by fewer men than would be needed for a shielded-cell-type operation.

Hot slugs are normally discharged into a deep basin filled with water for preliminary storage before transporting them elsewhere. The inspection station connects with the basin, so hot slugs can be inspected without exposing them to air, which would spread contamination. One man can move a bucket of slugs on a monorail. To move the slugs over the surface means hoisting them out of water and transporting them in a shielded railroad car. A train crew, a railroad, and unloading facilities would be needed.

First Inspection

The primary inspection station is the first stop. The cartridge of slugs is removed from the carrying bucket that has brought the slugs over from their discharge point. The cartridge is set on the basin floor. Slugs are loaded by long tongs into the feeder chute of the manipulator (Fig. 2 and cover).

At this first examination station, the entire slug surface is examined with a 10× periscope as the slug is being rolled. Three mirrors allow for examining the end caps of different length slugs. Slugs that are warped or show other outward damage are not acceptable for further processing because of small clearances in the equipment that follows. Such distortion is *prima facie* evidence of poor manufacture. Distorted slugs are rejected down a chute into a bucket for disposal.

Accepted slugs are moved by a transfer arm that picks up the horizontal slug, turns it over, and stands it on end in the cartridge fingers. This arm has wide fingers that form a guide when sliding the slug into the cartridge pocket. The fingers are actuated by means of a small water-pressure bellows. The arm itself is powered by a motor* designed for use under water.

The entire assembly is attached to one frame as a single unit. The unit has a mounting base plate. Only the base plate is fixed to the basin floor, so the assembly can be slipped off the base plate and lifted out of the water by a crane for repairs. Power piping from the surface to the pool bottom has slip fittings so the piping can be pulled out and set to one side when the equipment is removed.

The cylinders are water actuated. They are operated by pushbuttons and solenoid valves. All cylinders are installed in the retracted position when at rest, because of a sludge deposit that settles on the equipment. Gears and bearings are made of nylon to eliminate lubrication. Brass and stainless steel materials are used to reduce corrosion.

Slug Cleaner

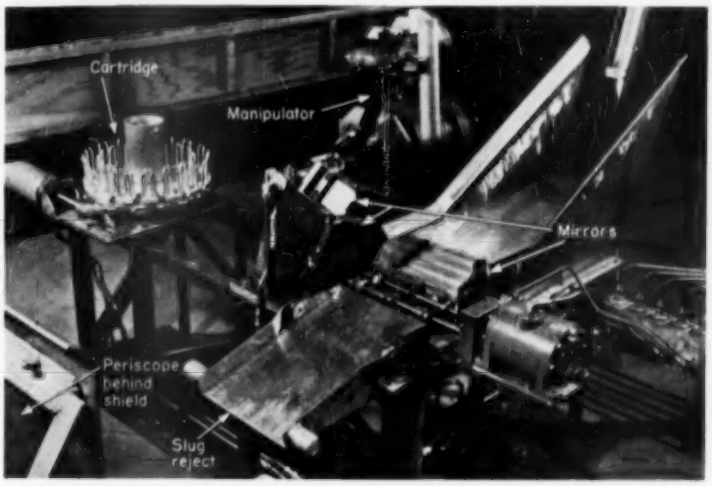
A full cartridge of slugs may be placed in the cleaner, washed in hot acid, rinsed, drained, and removed for further processing. The cleaner (Fig. 3) stores hot acid during rinsing and loading. It is made of stainless steel.

The equipment sits on a stainless steel base plate with positioning holes. Dowels mounted in the basin floor guide the cleaner into exact orientation. A swinging jib crane with a hydraulic lift cylinder is mounted in the basin. The crane is carefully located so that it can pick up a cartridge of slugs, put the cartridge in the cleaner, remove it, and set it on transporting equipment. The crane is also used for lifting the cleaner from the basin when maintenance is required. Supply-line connections to the washer are made through a specially designed manifold. The manifold automatically forms watertight connections when the washer is set in place.

Operation. An electrical control console near the cleaner has a graphic panel. Setting the main control switch on "automatic" closes the cover and the main timer directs these operations:

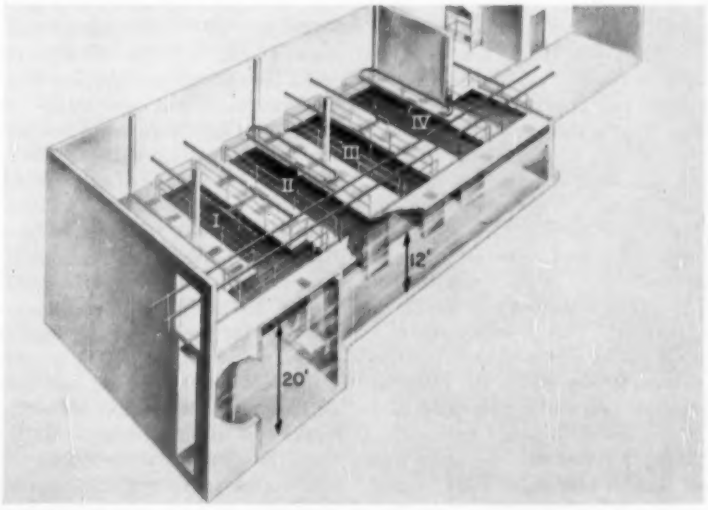
1. Basin water is forced from the wash tank by air pressure.
2. Storage-tank heater is turned off and 10% phosphoric-chromic acid at 80° C is forced by air pressure into the wash tank from storage.
3. Wash-tank heater and agitator (compressed-air sparger) are turned on and slugs washed for about 10 min in air-agitated water.
4. Wash-tank heater is turned off and storage-tank heater turned on. Gravity flow transfers the acid into the storage tank.
5. Wash tank is rinsed with fresh

1. Metal examination facility uses water shielding. Irradiated slugs are . . .



TEST EQUIPMENT is installed on the floor of these basins. Thus 20-ft depth of water shields basin I, 12 ft shields other basins. Operator stands at safety rail, crane and monorail system move samples from basin to basin

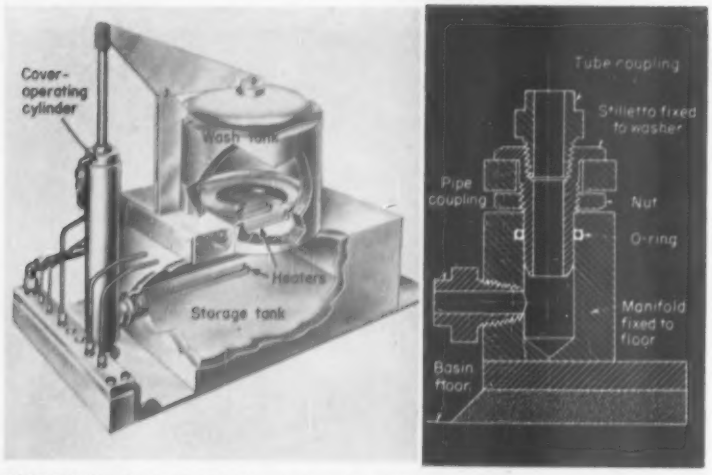
2. First sorted and examined at inspection station, put in carrying cartridge, and . . .



BELL CRANK powered by water cylinder operates two sets of fingers that allow one slug at a time to enter manipulating rollers. Slug surface is examined by 10 × periscope. Mirrors are arranged so slug end can be viewed. Accepted slugs are transferred by manipulator arm to slug-carrying cartridge. Cartridge holds 16 slugs vertically, using wire brackets. Rollers and fingers are of nylon, to prevent scratching

* Product of Hydromotor Div., Bonnot Co., Canton, Ohio.

3. Slugs are cleaned, using acid. Then . . .



TWO TANKS, both of stainless steel, enclosed in an insulated outer shell, comprise the slug cleaner. Upper tank is actual cleaner, where hot acid cleans aluminum surface. Bottom tank stores acid when it is not in use. Cleaner sits on a stainless steel base with positioning holes. Dowels mounted in the basin floor exactly position cleaner. Air pressure is used to transfer liquids. Detail shows manifold that automatically forms water-tight connection when cleaner is set in place. Upper tank is 24 in. in diameter by 24 in. high

water and drained to the process sewer.

6. A second fresh-water rinse enters and remains.

7. Wash-tank cover opens.

The cartridge of slugs is now picked from the cleaner by the jib crane and set on the dolly for further processing. The entire operation takes less than half an hour.

To save time, various liquid transfers and operations are actuated by electrical probes integrated with a program timer. However, it was not desirable to rely completely on probes because the tank can hold high-conductivity acid solution or low-conductivity water.

The program timer is similar to most types, consisting of a series of disks on a shaft driven by a synchronous motor through a gear drive. Each disk has a number of toggles to open and close its associated switch at the times desired. The timer can be started with a momentary contact. This is done by using a solenoid device that mechanically trips the contact from which the motor is controlled. An auxiliary device is used to adjust the wash period separately.

During acid transfer from storage to wash tank, a time-delay relay is used to assure a complete cycle of operation even if the acid doesn't contact the wash-tank acid-level probe. This is done because it is desirable to complete a cycle once it is started. Compressed air entering the tank through the vent line is used to force spent acid from storage tank to process drain. Fresh acid is added through the acid make-up line by gravity flow.

Piping. The cleaning tank is connected to the storage tank and to the outside process drain by stainless steel tubing. In this transfer line is mounted a specially made, stainless-steel, three-way, pilot-operated valve with spring return to "off." This valve directs cleaning acid in either direction between the storage and cleaning tanks, or allows basin and rinse water from the cleaning tank to go to process drain. The three-way drain valve can be bypassed by a drain line from the storage tank to the process sewer. A shut-off valve in the drain bypass may be remotely operated from the operating floor using a long handle and key. This is done when it is necessary to drain direct from storage tank to process sewer.

Hydraulic or pneumatic valves are used so a minimum number of electrical leads will be underwater. Air and water, in turn, are controlled by solenoid valves above the water surface. Three-way solenoid valves operate the cover cylinder and the air or vent line to storage tank. Two 3-way solenoid valves operate the drain valve.

A float switch in the wash-tank vent line at basin-water level, together with the timer, prevents rinse water from flooding the vent line. At the same time the switch allows water to completely fill the tank for rinsing. The second filling relieves basin water pressure on the tank cover so it can be operated easily.

The wash-tank cover is sealed against leakage by a soft Neoprene gasket cemented to the ledge formed by the outer insulating compartment. The wash-tank cover is a stainless steel dished head with a smaller insulated dished head mounted inside and concentric to it. Because the outer dish is cooled by cold basin water, it offers a cold surface to condense hot vapors that may otherwise enter the vent. The vent line is attached to the washer cover by a swivel coupling. To further reduce the possibility of hot vapors escaping, another condenser is used in the vent line. The submerged condenser is cooled by basin water.

The slug cartridge sits on a ceramic disk on a rack in the wash-tank bottom. This precludes galvanic action between the slugs and tank walls.

Equipment installed nearby is so sensitive to cloudy water that every precaution is taken to ensure no acid retention pockets in the wash tank or lines. Even minute amounts of acid will cloud the water. A fresh-water rinse from an outside source is used instead of basin water. The second rinse reduces the likelihood of acid getting into the basin water.

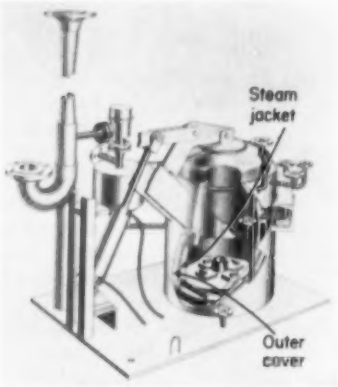
Slug Dejacketer

A chemical means for jacket removal was selected because mechanical methods are impractical. The design problem is to place underwater a chemical process vessel that would dissolve the aluminum can with a minimum of operator attention and maintenance.

The bare-slug examination facility is designed to examine 32 slugs per shift. Overnight exposure of uranium to water would cause uranium deterioration. Thus, three hours is allowed for dejacketing during the day shift.

The vessel (Fig. 4) is a cylindrical tank with a steam jacket enclosing the lower half and bottom. The tank and steam jacket are enclosed within an outer tank. The annulus between is filled with insulation. Top head of the vessel is a hinged cover actuated by a hydraulic cylinder through a linkage that is self-locking when the cover is

4. Selected slugs are dejacketed, using caustic



SELF-LOCKING linkage holds tank cover closed against 3,000-lb force, even if services fail. Dejacketter holds 20 gal. Steam jacket encloses tank bottom and lower half. Insulated outer tank encloses jacket. All piping is welded except for flanges shown. Cyclone-type separator in exit gas line removes foam. Inner tank is 15-in. in diameter by 24 in. high

closed. All piping into the vessel is welded wherever it passes through the sides to prevent leakage.

Chemical process. Sodium hydroxide removes the aluminum jackets with little effect on the uranium. End products are sodium aluminate, hydrogen and trace amounts of other gasses. Variable concentration and temperature control the reaction. Concentrated NaOH has high viscosity and a high freezing point. A 50% NaOH solution at the boiling point (290° F) was found best for removing the jackets. The minimum 10 gallons of caustic enters the tank at 260° F. It soon reaches the boiling point because the reaction is exothermic. Safety considerations and reduced control requirements in handling are the reasons for using 260° F. A second addition of 50% NaOH is required to remove the jacket quickly. This reaction, being less active, has to be heated by the steam jacket to quickly reach boiling. A 10% nitric acid solution then is used to remove any residue.

Chemicals are supplied from a trailer with permanently installed acid and caustic tanks. The tanks are insulated and steam heated. Flexible hoses with valved quick-disconnect couplings are used for convenience.

Two additional "volume measuring" tanks inside the building meter the quantity of acid and caustic. The caustic volume tank has a steam coil to raise NaOH temperature to 260° F before use. The vessel, caustic-addition, steam-supply, and liquid-waste lines require insulation because of the cool water that surrounds them.

The hydrogen evolved requires dilution to remove the explosion hazard. This is done by a centrifugal blower and an air-jet compressor that mixes the gases with motive air in the venturi section of the air jet. A cyclone-type separator in the exit gas line removes foam. The separator and the uninsulated cover prevent much condensible gas from entering the gas-jet compressor.

Equipment. The waste line is welded into a small sump at the tank bottom so compressed air can discharge the wastes, eliminating an underwater pump. Steam condensate is treated the same way except that steam pressure is used for discharging through a thermostatic trap above the water. All underwater lines are welded except for flanged connections near the tank that allow its removal.

The liquid-waste line is stainless steel. It exits through an above-water valve box that has thick concrete walls for shielding. Waste lines after leaving the valve box run underground. They end in three places, depending on the waste: (*a*) basin water goes to process sewer; (*b*) rinse water goes to underground cribs or process sewer; and (*c*) stripping chemicals go to permanent underground storage tanks.

The 10 lb/in^2 needed to discharge the NaOH creates ~3,000 lb force on the cover. To avoid too large an operating cylinder and special equipment to boost water main pressure, the locking linkage is designed to hold the cover closed. Shims are used to position the cylinder trunnion. The linkage positions the cover and its gasket.

Control. The process should be as automatic as possible to eliminate operator error and obtain predictable results. This, plus safety requirements, caused a complicated control system. Most operations, including the reactions and liquid transfers, are controlled by the timer. Exceptions are the full rinse (by float switch) and the metered spray rinse.

The control board has a graphic panel that indicates (by lights) cycle progress on a simplified flow diagram. The panel shows availability of the various services. The availability signals also close a relay, allowing the process to start.

The operator, using the jib crane, loads the vessel and presses the main timer button, starting the cycle.

First cycle. The lid closes and air pressure ejects the water inside the tank. Hot NaOH is added. Simultaneously an auxiliary timer is started to control the reaction, and reenergize the main timer when this part of the cycle is done. Air forces the depleted NaOH and sodium aluminate to waste. Two gallons of water are metered in as a spray rinse. During the cycle, caustic is transferred by gravity from the outside storage tank to the volume measuring tank, the liquid seeking its own level in a small vent line.

A pilot-operated valve in the aspirating line opens and closes on signal during the cycle to prevent loss of air pressure to the gaseous waste line and to prevent liquid from entering the air-jet compressor.

Second cycle. Caustic is added and steam admitted to the steam jacket. Another spray rinse follows after the waste is ejected. The steam supply is closed off after the second caustic reaction.

The acid bath is added after the spray rinse is ejected. Time that the acid remains in the tank is controlled by an auxiliary timer like the timers used for the first and second caustic reactions. The acid is discharged and followed by a spray rinse.

Two water rinses, each completely filling the tank, follow the acid bath. This operation is controlled by a float switch.

The tank is filled with water a third time and the lid opens to allow removing the dejacketed slugs. The tank is then ready for the next batch.

All valves are electrically controlled. They are constructed to be normally closed as a fail safe feature, except for the valve in the liquid-waste line that is normally open. As an additional precaution the waste valve is bypassed by a vertical loop around it. No valves are needed in the loop because the discharge head normally used is insufficient to flow over the loop. The four-port, three-position valve controlling the cover operating cylinder keeps the cover in the desired position even though water pressure or electrical power fails.

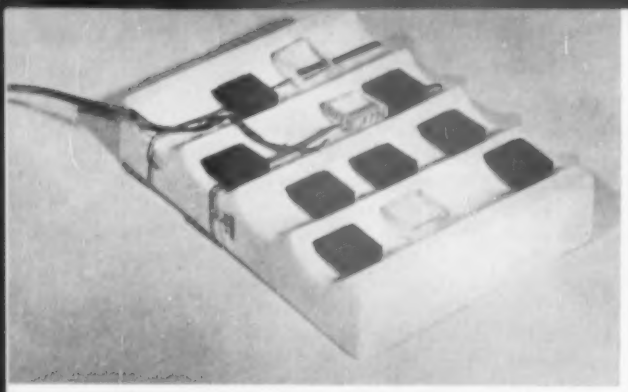


FIG. 1. Arrangement for removing radiation-induced darkening of glasses by heating

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Glass Dosimetry

Here's a thorough study of silver-phosphate glass as a dosimeter: the effects of storage temperature, how postirradiation heat treatment stabilizes fading, the effect of freezing temperatures during irradiation, and other parameters

PRODUCTION-LINE STERILIZATION of foods, drugs, and biological materials by ionizing radiations grows increasingly probable as technical problems are solved and the number of applications increases. It is a practical and legal necessity to measure doses accurately in these radiation processes, but most of the existing dosimetric systems, which are based on ionization or calorimetric principles, do not easily lend themselves to rapid, routine, and accurate measurements.

Investigations at the Naval Research Laboratory by Schulman and associates (*1, 2, 3, 12*) and here at MIT (*4, 13*) have indicated that the silver-activated phosphate glass, originally developed at NRL (*5, 6, 7*) to measure low personnel doses, has good potentialities for measuring high doses. In the measurement of high doses the optical absorption is used rather than the fluorescence properties used at the low doses.

The use of glass as a dosimeter has several advantages that make it especially attractive for use in this field. These include chemical inertness, rigidity, insolubility, small size, and permanence. A thorough investigation of those properties of silver-activated phosphate glass of importance in high-level dosimetry is reported here.

Apparatus and Methods

The glass used was Corning #9761. The composition is that originally specified at NRL, namely, 50% $Al(PO_3)_3$, 25% $Ba(PO_3)_2$, and 25% KPO_3, with about 8% $AgPO_3$ added.

Sources. The source of gamma radiation used was a multicurie Co^{60} source (*10*) with a dose rate of ~1,400 rep/min. The doses used were based upon experiments and calculations employing physical dosimetric methods and the ferrous-ferric dosimeter (*10*). The specific yield of the ferrous-ferric

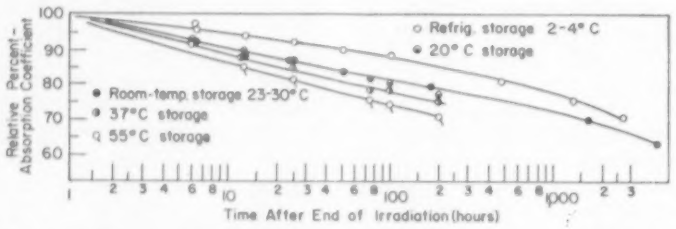


FIG. 2. Effect of storage temperature on irradiated silver-activated phosphate glasses not given heat treatment

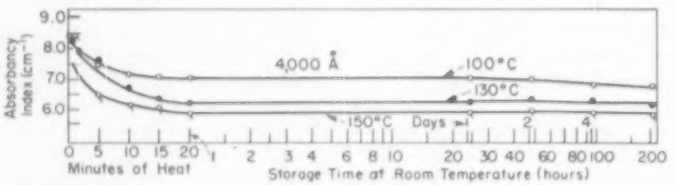


FIG. 3. Effect of heating temperature on irradiated glasses stored at room temperatures

* This paper summarizes work done by the Department of Food Technology, Mass. Inst. of Technology, on A.E.C. Contract AT(30-1)-1164 (*4, 13*).

reaction was taken as 15.4 μM Fe^{+++}/liter/1,000 rep.

A Van de Graaff accelerator was used as a source of 3-Mev electrons in some experiments.* Doses were calculated from meter readings of current and voltage in accordance with a previous method (*11*).

Irradiation. When the Co^{60} source was used, three to six replicate glasses were used in each determination, the glasses being stacked horizontally one on top of another in a cylindrical glass ampule (diameter, ½ in.; height, 1¼ in.) with stopper. All ampules were filled with water and irradiated in fixed positions in special sample holders, to match geometry and absorber characteristics to those used in source calibration.

Measurements. Optical density was measured in a Beckman DU spectrophotometer with photomultiplier attachment. A special metal sample holder with four matched apertures to accommodate three glasses and a "blank" was used. Aperture dimensions were 0.80 × 0.80 cm. The "blank" aperture is used as the 100%-transmission reference; the absorbancy index† is calculated by dividing the observed optical density by the measured thickness of the glass. Slit widths used were 0.4–0.5 mm, and each glass was measured at four wavelengths: 3,500, 4,000, 4,500, and 5,000 Å. [Where data are shown only for 4,000 Å see NYO-3345 (*13*) for more complete results.]

The absorbancy index reported here is the AI of the irradiated glass minus the AI of the nonirradiated glass.

Figure 1 shows the arrangement for erasing glasses. A Coors porcelain pipette rest (glazed except bottom) with thermocouple attached holds the glasses while in the oven and while cooling.

Experimental Results

The characteristics that follow were studied with a view toward practical utilization. The nature of these studies was also indicated by earlier results obtained by Schulman *et al.* (*1*, *3*). More complete data are contained in NYO-3345 (*13*).

1. Effect of storage temperature on irradiated glasses not given heat treatment. Experiments were conducted to determine the effect of storage temperature on fading characteristics of glasses irradiated with a gamma-ray dose of 1.30 × 10^5 rep. Six glasses were stored at each of five temperatures in °C: room temperature (23–30°), refrigerator temperature (2–4°), 20°, 37°, and 55°. No differences are evident between 20°, 37° and room temperature for about the first week of storage with the exception of the 4,000 Å measurements where a small difference was noted for the 37° temperature as compared to 20° and room temperature (see Fig. 2).

Appreciable differences are apparent for the refrigerator and 55° temperatures as compared with the other three temperatures. Thus extremes in storage temperature should be avoided. Cold and hot storage temperature retard and accelerate fading rates, respectively, of glasses not given a stabilizing heat treatment.

2. Effect of heat treatment after irradiation. Glasses irradiated with a gamma-ray dose of 3.70 × 10^5 rep were heated, 60 min after irradiation, to temperatures of 130° and 150° C. (Temperatures were achieved with a small precision furnace and measured by a thermocouple placed close to the glasses.) Glasses were also heated to 100° C in boiling water. Figure 3 presents the absorbancy indexes observed (1) immediately after heating for 5, 10, 15, and 20 min at the different room temperatures and (2) after 1, 2, 4, and 8 days of storage at room temperature. The data at each temperature indicate that:

- The light absorption decreases with time and temperature of heating.
- The curves begin to flatten out after ten min of heating.
- There is little additional decrease in light absorption after about 15 or 20 min of heating at the three temperatures.
- The fading at room temperature is reduced considerably after the heating process, decreasing from about 8% after eight days in the 100°-C experiment to about 4% after eight days in the 150°-C experiment (4,000 Å).

These experiments indicate the usefulness of heating the glass to reduce the rate of fading after irradiation, although heating does not eliminate all

Probable Percentage Limits of Error*

Wavelength (Å)	*One glass* (%)	*Mean of three glasses* (%)
3,500	±3.3	±1.9
4,000	±4.2	±2.4
4,500	±4.7	±2.7
5,000	±5.4	±3.1

* For Corning 9761 glass on the basis of 48 irradiations at ~1.30 × 10^5 rep. Probability level is 99%.

* We wish to express our appreciation to J. G. Trump and K. A. Wright of the Department of Electrical Engineering, Mass. Inst. of Technology for their continuing cooperation in making available the facilities of the Van de Graaff accelerator and for calculation of the electron doses.

† The absorbancy index (AI) is related to the absorption coefficient (AC) by the factor $\log_e 10 = 2.3$. Thus, AC = 2.3 × AI.

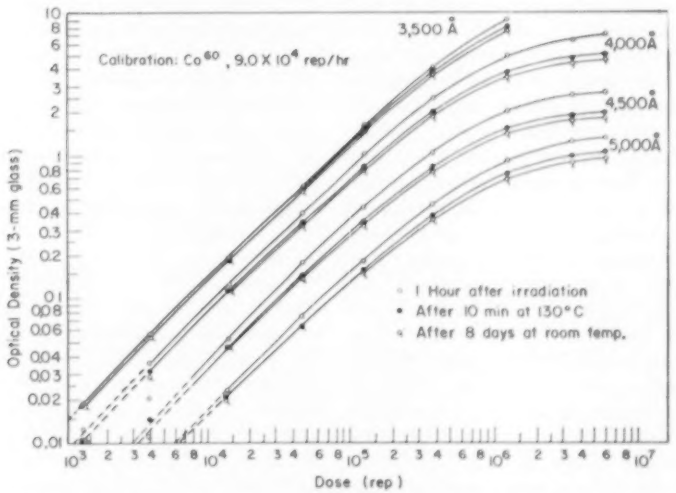


FIG. 4. Calibration of silver-activated phosphate glass irradiated with Co^{60} gamma rays: measured before heating, after heat treatment for 10 min at 130° C, and after 8-day storage at room temperature

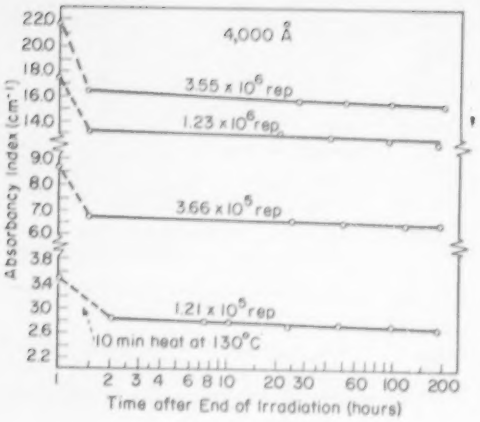

4,000 Å
3.55 x 10^6 rep
1.23 x 10^6 rep
3.66 x 10^5 rep
1.21 x 10^5 rep
10 min heat at 130°C
Absorbancy Index (cm^-1)
Time after End of Irradiation (hours)

FIG. 5. Fading characteristics of silver-activated phosphate glass given different doses, heated for 10 min at 130° C, and stored at room temperature

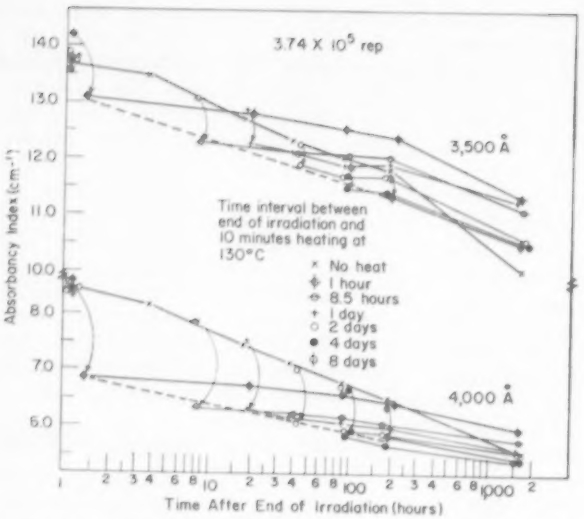


FIG. 6. Effect of heating glasses for 10 min at 130° C, after different time intervals at room temperature following dose of 3.74 × 10^5 rep

fading in glass of this particular composition.

3. Effect of storage temperature on glasses given heat treatment. A 10-min post-irradiation heating at 130° C has been used to minimize the effect of storage temperature such as observed in Fig. 2.

Three groups of three glasses each were irradiated with a gamma-ray dose of 3.66×10^5 rep. One hour after irradiation the glasses were measured and then heated for 10 min at 130° C. They were then measured again. One group was stored in a refrigerator (2–4° C), one at room temperature (23–26° C), and the third in an oven maintained at 43° C. Measurements were taken during an 8-day period on the three groups.

The data show no significant difference with storage temperature (except at the eighth-day measurement when a small lowering in readings for the glasses held at 43° C was detected). Thus an additional virtue of heat treatment after irradiation is the considerable decrease of the dependence upon storage temperature of readings made long after irradiation.

4. Calibration curves. Figure 4 shows calibration curves at four wavelengths from data obtained by irradiating glasses (six at each dose level) with gamma-ray doses ranging from about 1.3×10^3 rep to 7×10^6 rep. Sixty min after irradiation, these glasses were heated for 10 min at 130° C. An extra minute was allowed for the glasses to reach the desired temperature after insertion into the oven. Following irradiation, measurements were taken before heating, within 30 min after heating, and after 8 days of storage at room temperature. Each point shown in Fig. 4 is the average of six measurements.

It is apparent that the slopes of the curves decrease appreciably above $\sim 3 \times 10^5$ rep. Consequently, sensitivity of the glass in this region is reduced. Precise experimental techniques and reproducibility of glass characteristics become increasingly important to obtain accurate results.

The percentage of fading, both during the heating period and during the 8-day storage period, decreases significantly with lower doses. In fact, when the dose is below 4×10^4 rep, fading becomes almost negligible during the 8-day period after heat treatment.

5. Fading of glasses given heat treatment after different doses. Figure 5 shows measurements of the absorbancy index at 4,000 Å observed after four different doses. The measurements were taken 1 hour after irradiation, after 10 min of heating at 130° C, and at various times up to the eighth day of room-temperature storage.

A fairly good approximation to the fading for the first 8 days after irradiation is given by the equation shown above

$$AI = a \ln t + b \qquad (1)$$

where AI is the absorbancy index observed at a time t after irradiation, and a and b are functions of the dose and wavelength, but are constant for a given dose and wavelength.*

6. Effect of heating glasses after different postirradiation waiting periods. In experiments described thus far heat treatment was used 1–1½ hours after irradiation. In practice heat treatment may not be convenient if it is necessary to apply it so soon after irradiation. A series of experiments was, therefore, conducted to study the behavior of the glass when it was heated after different time intervals following irradiation.

Twenty-one glasses were irradiated with a dose of 3.74×10^5 rep. The glasses were separated into seven groups of three each, and all were measured one hour after the irradiation. Over a period of 8 days, each of six groups was given a 10-min heat treatment at 130° C, at different times after irradiation, including 8.5 hours, 1, 2, 4, and 8 days, and about 2 months. The seventh group was allowed to fade at room temperature without heat treatment. All the glasses were measured at various times after heat treatment up to the eighth day following irradiation, including measurements im-

* Measurements taken at 3,500, 4,500, and 5,000 Å show the same linearity (*13*).

mediately following the heat treatment.

Figure 6 presents the absorbancy-index values obtained as a function of time, and includes previous data where heat treatment was made one hour after irradiation. It is evident that *immediately following heat treatment* the absorbancy indexes drop to values approximately linear (dashed curve) with respect to the logarithm of the time, for all the time intervals between irradiation and heating (from 1 hour to 8 days) that were tested.

However, *subsequent to* the initial measurement after the heat treatment the absorbancy indexes of a given group of glasses have, in general, a different linear relationship with respect to time. Fading following heat treatment proceeds at a lower rate than that shown by the curve based on measurements taken immediately following heat treatment applied at different intervals.

This would seem to suggest that the heat treatment not only eliminates some of the more unstable centers but alters the stability of some of the remaining centers so as to *reduce* their probability of fading. This is verified by noting that the absorbancy indexes of glasses not given heat treatment, in several cases, fall below glasses given heat treatment.

These results indicate that if heat treatment is to be applied at different time intervals following irradiation, one should not correct for the time interval by utilizing data on fading following heat treatment one hour after irradiation. Rather, it would be preferable to employ actual curves obtained by heating glasses after different time intervals. These curves appear to be fairly good linear plots with the logarithm of the time, so that measurements after two widely spaced time intervals such as one hour and one week will yield data sufficient for interpolations within this range.

7. Effect of freezing temperature during irradiation. Sometimes irradiation at temperatures below 0° C is a means of minimizing some of the undesirable chemical and physical changes produced by radiation. Accordingly studies were initiated on the dosimetry of materials frozen while being irradiated.

Figure 7 shows the results of an experiment where two groups of glasses were given a dose of 3.66×10^5 rep, heated for 10 minutes at 130° C, then stored at room temperature. One group of glasses was frozen in water during the irradiation whereas the other was irradiated at room temperature. Significant differences are apparent, with the glasses irradiated at the freezing temperature showing consistently lower readings.

The conclusion is that the silver-activated phosphate glass dosimeter can be used for frozen materials if a correction factor is applied to calibration charts constructed from results of irradiation at room temperature. Alternatively, calibration charts should be constructed from data obtained from glasses irradiated at freezing temperatures.

High-temperature Erasure

Preliminary experiments showed that exposed glasses may be "erased" (i.e., the coloration caused by irradiation removed) by application of 400–500° C temperatures. Further experiments were conducted to determine how the sensitivity of the glass varies with repeated erasures and how many repeated erasures are possible.

Fifteen minutes at 450° C was found sufficient to erase these glasses after doses up to 5×10^6 rep.

The results obtained after five successive exposure-erasure cycles, where the dose in each exposure was 1.24×10^5 rep and the glasses were measured one hour after irradiation, are given in NYO-3345 (*13*). No definite increase or decrease in sensitivity of the glasses with repeated exposure-erasure cycles is observed.

A series of ten successive exposure-erasure cycles was conducted in the high-dose region, doses being chosen randomly in the region of $2.5–50 \times 10^5$ rep. The average values for a group of three glasses are plotted on curves determined for nonerased glass from the same lot (Fig. 8). The points on the curves are marked to show the sequence of the exposure-erasure cycles. It is evident that the glass behavior remained essentially constant even after ten successive erasure-exposure cycles. Furthermore, the fading behavior observed in cycles 8, 9, and 10 remained unchanged from that of the original glass.

It seems that these glasses can be reused after erasing at high temperature; this reuse will add considerably to the value of the glass as a dosimeter.

How Precise?

Because of the large number of glasses whose optical densities were measured under identical conditions in this investigation, it has been possible to compile sufficient data for statistical analysis of the reproducibility characteristics of Corning 9761.

The table on p. 35 presents probable percentage limits of error determined from a total of 48 glasses irradiated under nearly identical conditions* over a period of two months. These glasses were all from the same lot and all received a dose of about 1.30×10^5 rep.

Optical density measurements on nineteen non-irradiated glasses from the same lot were also analyzed statistically. The ranges of values calculated at a 99.7% probability level were typically 0.045 ± 0.007 at 4,000 Å.

It may be concluded that no appreciable increase in precision is obtained if individual glasses are measured before irradiation with doses of 10^5 rep or greater. The mean values of a few nonirradiated glasses from the same lot will suffice for the preirradiation absorption corrections. However, at the lower dose levels, where the preirradiation readings represent a larger percentage of the postirradiation read-

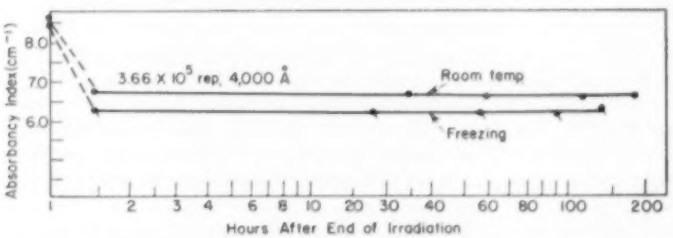


FIG. 7. Fading characteristics of glass given dose of 3.66×10^5 rep at two different temperatures, heat-treated for 10 min at 130° C, and stored at room temperature

* Slight differences in dose due to length of irradiation or source decay were compensated by correction of the optical readings before statistical analysis.

ings, individual preirradiation measurements are advisable.

Fading Corrections

We have demonstrated that fading occurs after irradiation, whether the glass is heated or not (although subsequent fading is reduced appreciably by heat treatment). The possibility of applying corrections to the glass measurements to compensate for fading is evident if a relationship between the rate of fading and the time after irradiation can be developed.

The nomogram in Fig. 9 provides a simple method for utilizing Eq. 1. The left-hand scale is a logarithmic time scale extending from 1 hour to 1 year. The change of optical density (fading change) between 0 and 8 days after irradiation corresponds to the area between the curve in Fig. 4 for readings after 10 min of heating and the curve for readings after 8 days of storage.

The right-hand scale is graduated in linear units with unity corresponding to the 8-day period.

Electron-beam Dosimetry

Work by this laboratory (reported in the article (*3*) by Schulman, Klick, and Rabin) has shown the feasibility of using silver-activated phosphate glass for dosimetry 3-Mev electron beams. Since the intensity of ionization in matter falls off much more rapidly for electrons than for gamma rays* it is of importance to determine the effect of placement of the glass when it is used as a dosimeter for electron beams, and the possible effect of variation of ionization density in the glass itself because of its appreciable thickness compared with the maximum range of the electron beam.

A previous calibration of the silver-activated phosphate glass dosimeter is needed for interpretation of the changes in absorption after receiving doses of high-energy electrons. The Co^{60} gamma-ray calibration of the glass, Fig. 5, can be used for this purpose. However, the relative duration of irradiation must be taken into account. For example, the Van de Graaff accelerator used in this work, delivers a 10^6-rep dose in about 10 sec whereas the Co^{60} source, used for calibration, delivers the same dose of gamma rays in about 12 hours. The difference in fading during the two irradiations must be taken into account. This has been done in these experiments by exposing more than one set of glasses to the same dose of electrons and measuring them at two different time intervals after irradiation.

Two stacks were assembled, each consisting of seven glasses of approximately 0.12-cm thickness one on top of the other. The stacks were secured with Scotch tape. They were then irradiated with the surfaces of the glasses perpendicular to the direction of the beam. The energy of the electrons was 3 Mev and the beam current was adjusted to deliver a dose of 10^6 rep in the region of maximum ionization density (at an average dose rate of 3.6×10^6 rep/min). After irradiation, the glasses were given heat treatment of 10 min at 130° C, group "B" receiving it one hour after irradiation and group "C" receiving it one day after irradiation. Measurements were taken of both groups of glasses immediately following heat treatment. Doses were determined from the calibration chart constructed from Co^{60} exposures (Fig. 5), by using the values obtained immediately after heat treatment applied one hour after irradiation. Depth-dose curves were drawn from apparent doses received by the top six glasses in each group. The seventh and bottom glass in each group apparently was beyond the range of the beam, as it received no detectable dose.

The abscissae in the figure are in terms of absorber thickness, obtained by multiplying the distance of penetration by the density of the material, so that materials of different density may be compared. The ionization density curves for the glass show the characteristic rise to a maximum. After the maximum is reached, the curves fall off rapidly to a value close to zero.

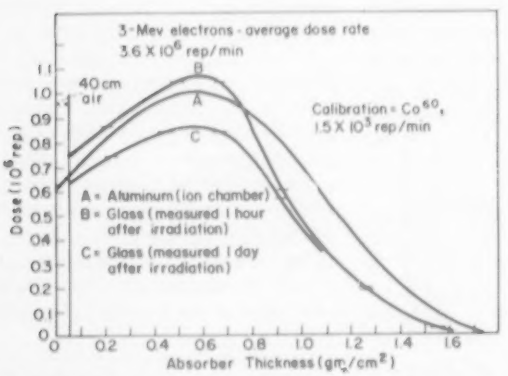
The "true" curve for glass should lie between curves B and C. This is because the 1-hour and 1-day waiting periods for curves B and C are shorter and longer respectively than the irradiation times for corresponding doses involved in the Co^{60} calibrations.

The figure above also shows a 3-Mev-electron ionization-density curve for aluminum (*11*), with the maximum at 10^6 rep. The three curves are similar in shape, and the maxima appear at the same absorber thickness. The maximum range in the aluminum is about 0.2 gm/cm² greater than in the glass. Furthermore, the ionization density in glass as determined by both groups of glasses remains appreciably lower than that in the aluminum shortly after the maximum values are exceeded. The explanation for these differences is not known, but the differences are likely caused by a difference in the scattering properties of the aluminum and glass.

The dose rates of the Van de Graaff and Co^{60} sources were in a ratio of ~2,000:1. The Van de Graaff results thus support the results of Schulman, Klick, and Rabin (*3*) who found no significant dependence of glass sensitivity on dose rate.

These experiments illustrate the applicability of this glass for electron-beam dosimetry and stress the importance of placement and geometry of the dosimeter system in interpreting correctly the dose received.

* The effective range for electrons is about 0.5 cm. for each Mev of energy in a substance of unit density.


3-Mev electrons - average dose rate
3.6 X 10⁶ rep/min
40 cm air
Calibration = Co⁶⁰, 1.5 X 10⁵ rep/min
A = Aluminum (ion chamber)
B = Glass (measured 1 hour after irradiation)
C = Glass (measured 1 day after irradiation)
Dose (10⁶ rep)
Absorber Thickness (gm/cm²)

DEPTH-DOSE CURVES in glass, as determined by self-dosimetry, compared with that in aluminum (*11*)

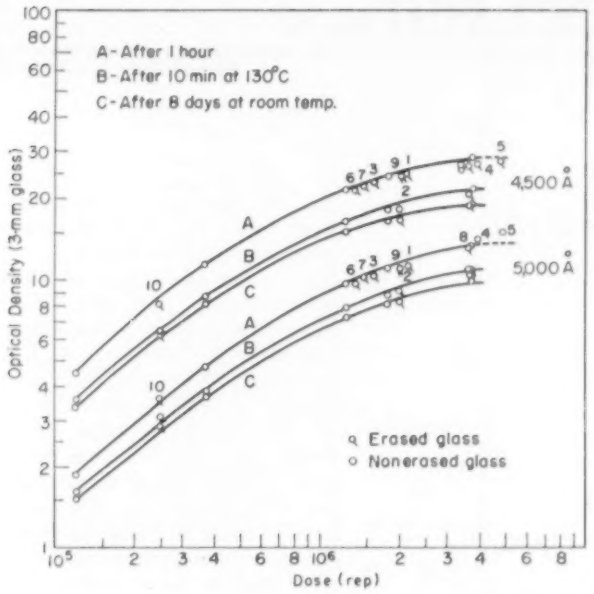


FIG. 8. Comparison of optical densities of nonerased glasses and glasses subjected to ten successive exposure-erasure cycles

FIG. 9. Nomogram for estimating decrease in optical densities of glasses after different time intervals following irradiation and heating

An example can best illustrate this use of the scale. Assume that an optical density of 1.00 (3-mm glass) is obtained at 4,500 Å, three days after the irradiation (glass was heated, 60 min after irradiation, for 10 min at 130° C). The time scale shows that 3 days represents about four-fifths of the distance to 8 days. An optical density reading of 1.00 intercepts the fading area between the two curves at doses corresponding to the dose range of 4.7–5.30 $\times 10^5$ rep. However, it intercepts the fading area four-fifths of the vertical distance between the fading curves, at about 5.15×10^5 rep. (Linear interpolation of the logarithmic scale is reasonably accurate for small time intervals). The total dose is, therefore, 5.15×10^5 rep.

Use of Fig. 4 for a calibration curve when other sources or dose rates are used must take into account fading during irradiation, if the exposure is long. The fading that takes place during irradiation is not known. However, the use of the heat treatment after irradiation will reduce appreciably the effect of the amount of time that elapses after irradiation, since it apparently eliminates the centers that are most unstable and that have a high probability of fading in the initial periods. For greatest accuracy, calibration doses should be delivered in times comparable with those to be encountered in use.

Considerations for Use

Restrictions in the use of the silver-activated phosphate glass dosimeter, such as avoidance of extreme temperatures and excessive exposure to light, are not difficult to fulfill in practice. Fading during and after exposure, and the energy dependence below 200 kev (7) are disadvantages, but these can be minimized by various techniques and do not detract appreciably from the value of the dosimeter.

Megarep dosimetry is not precluded by the appreciable decrease in sensitivity there. It is necessary, however, to apply careful experimental techniques to attain the precision that is readily available with lower doses. The degree of precision desired is variable with different needs and the latter should dictate the experimental methods used in this high-dose region.

It would be desirable for suppliers of this glass to develop formulations that would saturate at higher dose levels than silver-phosphate glass. This would help develop glass dosimetry to its fullest potentialities.

BIBLIOGRAPHY

1. J. H. Schulman, NRL Memorandum Report 266 (1954)
2. H. Rabin, NRL Memorandum Report 309 (1954)
3. J. H. Schulman, C. C. Klick, H. Rabin, NUCLEONICS **13,** No. 2, 30 (1955)
4. B. E. Proctor, S. A. Goldblith, A.E.C. Quarterly Progress Report July 1, 1954 to September 30, 1954, on Contract AT(30-1)-1164.
5. J. H. Schulman, R. J. Ginther, C. C. Klick, R. S. Alger, R. A. Levy, *J. Appl. Phys.* **22,** 1479 (1951)
6. J. H. Schulman, W. Shurcliffe, R. J. Ginther, F. H. Attix, NUCLEONICS **11,** No. 10, 52 (1953)
7. J. H. Schulman, R. J. Ginther, C. C. Klick, NRL Reprint 65–52 (1952)
8. M. Eicher, Developmental study of the use of Vycor glass for gamma ray dosimetry. Research Report, Project NM 006 012. 04. 09 Vol. 12, 147–166, May 1954, Naval Medical Research Institute
9. G. E. Blair, Data on a megaroentgen dosimeter system. (Bausch and Lomb Chemical Research Lab. Report, 1955)
10. S. Davison, S. A. Goldblith, B. E. Proctor, M. Karel, B. Kan, C. J. Bates, NUCLEONICS **11,** No. 7, 22 (1953)
11. J. C. Trump, K. A. Wright, A. M. Clarke, *J. Appl. Phys.* **21,** 345 (1950)
12. H. Rabin, W. E. Price, NUCLEONICS **13,** No. 3, 33 (1955)
13. B. E. Proctor, S. A. Goldblith, S. Davison, NYO 3345 (1955)

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Contribution No. 275, Department of Food Technology, Massachusetts Institute of Technology, Cambridge, Mass.

Gamma-Ray Attenuation

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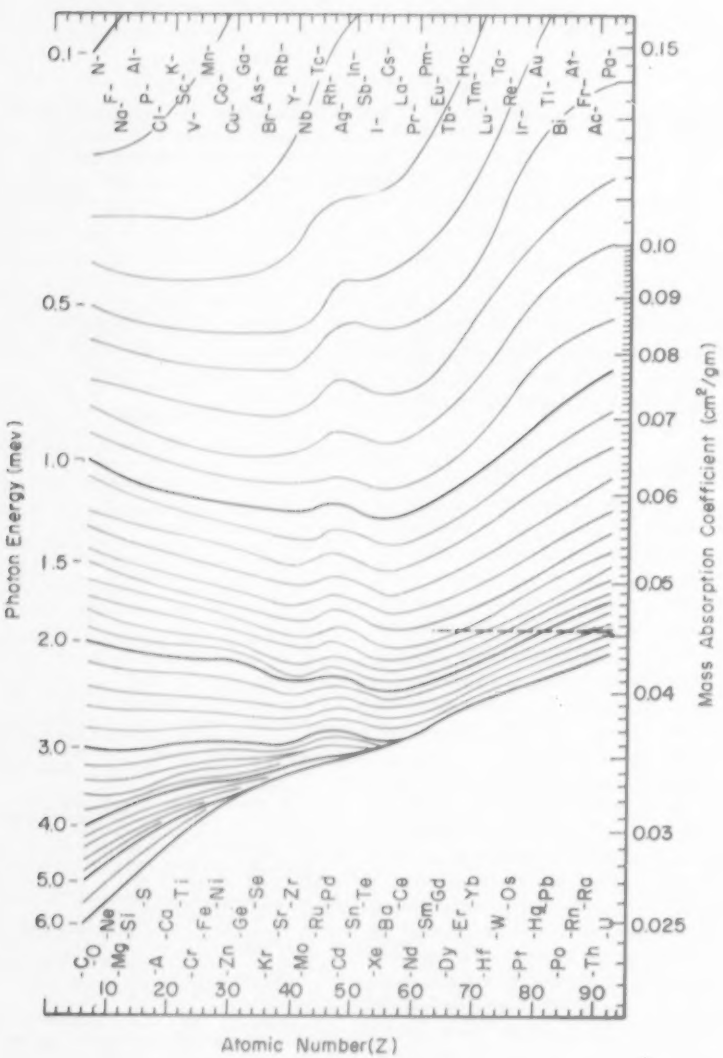


In calculating attenuation of gamma-rays, one must determine the mass absorption coefficient, μ_m. The μ_m for a number of elements has been calculated, (*1*). The value for other elements is obtained by interpolation. Hullings did this for five energy groups (*2*). Recently Moteff extended the list of available energy plots to 25 elements (*3*). However, complete tables of μ_m from 0.5 to 6 Mev, the usual range of interest, for all elements are still unavailable. The plot of μ_m vs Z below facilitates interpolation to any atomic number and energy. The data is taken primarily from Moteff (*3*).

Energies greater than 6 Mev have been neglected since for these energies and for Z = 30–94 μ_m is defined quite well by the 6-Mev curve, the locus of minimum absorption coefficient. This is generally used for shielding calculations for any energy above 6 Mev (*4*). For Z = 1–29, μ_m determined from the chart is slightly high for energies greater than 6 Mev.

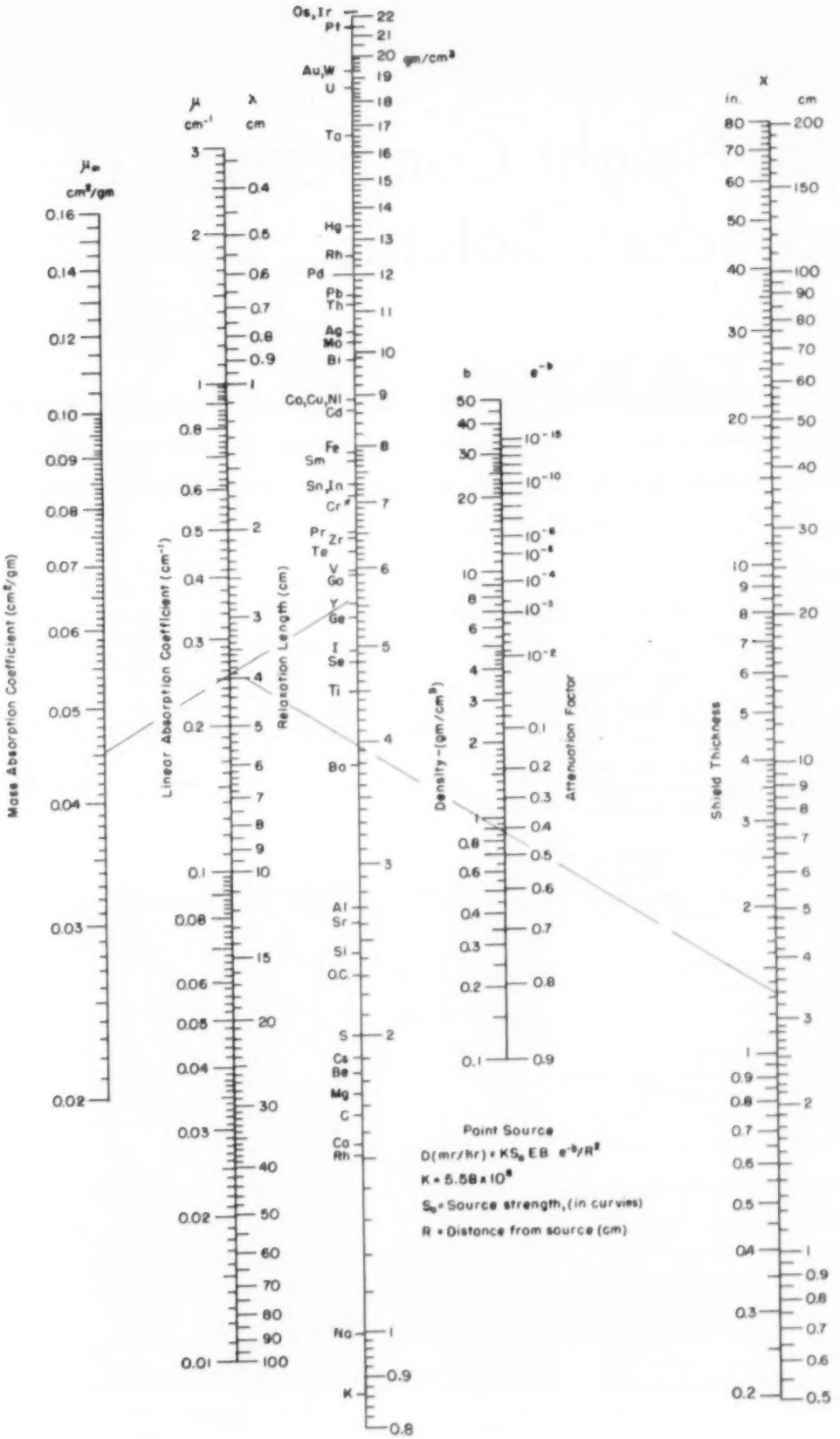
The nomogram on p. 41 can be used to convert μ_m to the linear absorption coefficient, μ, by multiplying by the density of the shield material, ρ. If μ is connected to the shield thickness, x, the shield attenuation factor for a point source with unit build-up, e^{-b}, is obtained ($b = \mu x$). The approximate build-up factor, B, for most elements, but not lead, up to 3 Mev is $1 + b$ and for lead over the same range $1 + \frac{1}{2}b$. The corrected attenuation factor is $B \times e^{-b}$.

Source strength (γ/cm²/sec) for an infinite plane source is approximately $\lambda/2 \times Q_v$, where Q_v is the specific activity, γ/cm³, of the source material. If μ is determined for the source γ-ray, λ can be read on the adjacent scale.

BIBLIOGRAPHY

1. G. R. White, NBS 1003 (1952)
2. M. K. Hullings, ORNL CF 53-2-266 (1953)
3. J. Moteff, APEX 176 (1954)
4. R. Stephenson, "Introduction to Nuclear Engineering," p. 185 (McGraw-Hill Book Co., Inc., New York, 1954).

* Knolls Atomic Power Laboratory is operated by the General Electric Co. for the U. S. Atomic Energy Commission under Contract W-31-109 Eng-52.


Mass Absorption Coefficient (cm²/gm)
μm
cm²/gm
Linear Absorption Coefficient (cm⁻¹)
μ
cm⁻¹
λ
cm
Relaxation Length (cm)
Os,Ir
Pt
Au,W
U
Ta
Hg
Rh
Pd
Pb
Th
Ag
Mo
Bi
Co,Cu,Ni
Cd
Fe
Sm
Sn,In
Cr
Pr
Zr
Te
V
Ga
Y
Ge
I
Se
Ti
Ba
Al
Sr
Si
Cc
S
Cs
Be
Mg
C
Ca
Rh
Na
K
gm/cm³
Density - (gm/cm³)
b
e⁻ᵇ
Attenuation Factor
Point Source
D(mr/hr) = KS₀ EB e⁻ᵇ/R²
K = 5.58 x 10⁵
S₀ = Source strength, (in curves)
R = Distance from source (cm)
Shield Thickness
X
in.
cm

Pulse-Height Comparison of Secondary Solutes

Double-solute liquid scintillators can give greater pulse height and less absorption than single-solute systems. The best secondary solutes are POPOP and BBO; here are confirming data for 24 compounds and large-detector results for some

THE LIGHT-EMITTING COMPOUND in a double-solute liquid scintillation system is known as the *secondary solute*. Its role is to receive excitation energy from the primary solute and to emit it as photons distributed with a characteristic spectrum. This spectrum is often much more desirable than the shorter wavelength spectrum derived from primary solutes for the following reasons:

1. Longer average mean-free-path in the scintillator.
2. Much better reflectance by titanium dioxide, the most popular internal reflector.
3. More efficient matching to the photomultiplier sensitivity curve.

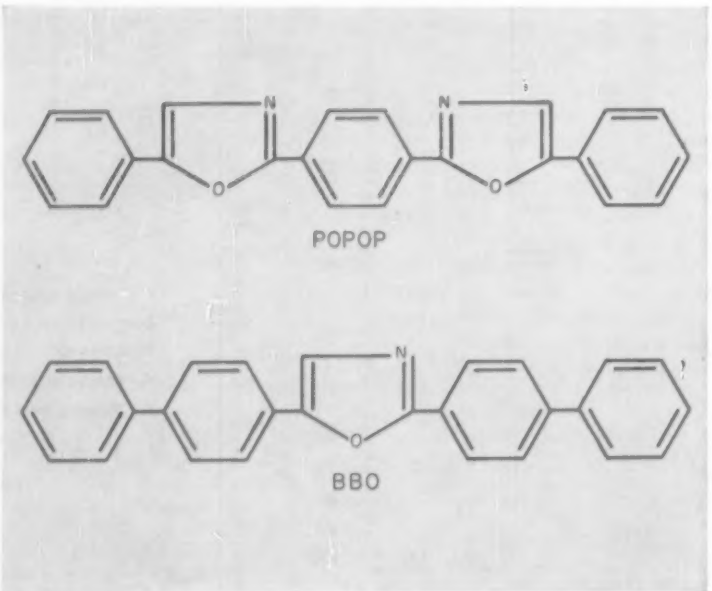
The secondary solutes are usually too insoluble, too expensive, or too high in self-quenching to function as primary solutes. Their usefulness follows from the low concentrations needed in practice. These concentrations are about one-hundredth those of the primary solutes.

The liquid scintillator program of the biomedical research group at Los Alamos has synthesized a number of compounds (*1*) with sufficient molecular complexity to be worth testing as secondary solutes. These compounds have been reported (*2*) in a primary solute study and they were chosen because they had large relative pulse heights and seemed to be long-wavelength emitters.

Testing Methods

Secondary solutes find their greatest application in large-volume liquid-scintillation detectors. Their major function is to make the shape of the scintillation spectrum such that the photons are efficiently transmitted and reflected.

The relative-pulse-height testing method used with primary solutes (*2*) can be applied to secondary solutes. However, the results with short light paths can fail to yield a proper indication of relative usefulness in large detectors. As one means of attempting to attain close correlation of pulse



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University of California
Los Alamos, New Mexico

heights and large-detector data, titanium dioxide has been used as the reflecting surface in this study. This followed from its sole use to date in all successful large scintillation detectors (*3, 4*). An aluminum reflector was used in one series of measurements whose results appear in the table on p. 44 as relative-pulse-height reflector ratios.

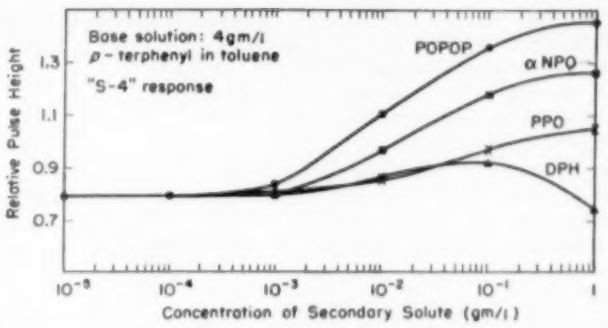
All solutions were prepared with toluene as the solvent and with *p*-terphenyl or 2,5-diphenyloxazole (PPO) as the primary solute. The standard solution was 3 gm/l PPO in toluene.

Three DuMont 6292 photomultipliers were selected for this study from a large group of such tubes. The basis of selection was an index of spectral sensitivity, namely the ratio of relative pulse heights from a solution of 4 gm/l *p*-terphenyl with 0.1 gm/l POPOP and a solution of 4 gm/l *p*-terphenyl. If all DuMont 6292 tubes followed the nominal S-9 spectral response curve, then the "spectral sensitivity index" should be constant within a group of such photomultipliers. As expected, this conclusion was found to be false and, from the range of values obtained, the two most different tubes were chosen, one having a shorter wavelength spectral response than the other. The former was designated "S-4" and the latter "S-9." These two were used in the early exploratory phases of this study. A third tube with average spectral characteristics was chosen for the general survey of twenty-four secondary solutes.

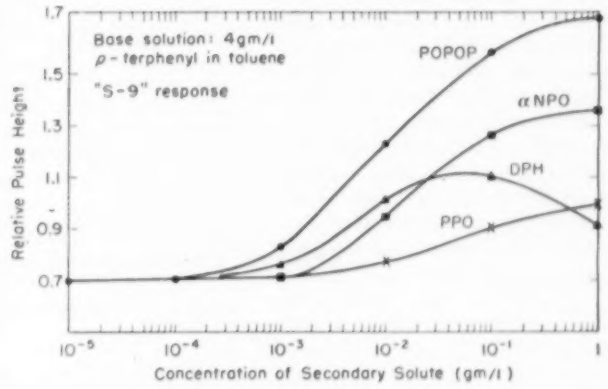
To study the correlation between 1-ml relative-pulse-height results and performance in large detectors, five of the more interesting solutions were tested in volumes of about 60 l, as fillings for a Los Alamos detector (*5*) used in basic nuclear physics research.

Secondary Solutes Now in Use

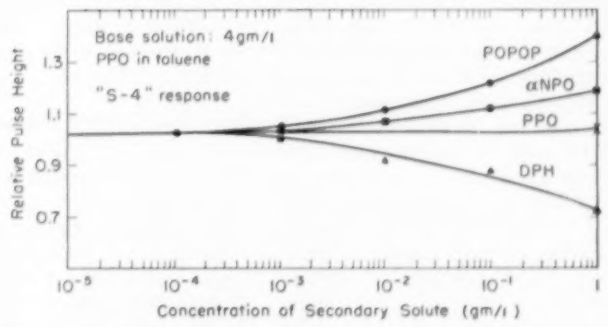
As a prelude to this study, it was decided that a detailed investigation of the secondary solutes in popular use should be carried out. These compounds are 1,6-diphenyl-1,3,5-hexa-



1 Pulse height versus secondary-solute concentration. Primary solute is *p*-terphenyl



2 Pulse height versus secondary-solute concentration. Primary solute is *p*-terphenyl



3 Pulse height versus secondary-solute concentration. Primary solute is PPO

triene (DPH) (*6*); 2-(1-naphthyl)-5-phenyloxazole (αNPO) (*3*); PPO (*7*); and POPOP (*5*). The choice of primary-solute concentration followed from the observation that addition of the secondary solutes, POPOP or DPH, at 0.1 gm/l gave pulse-height: concentration curves with shapes identical to that of the single solute, PPO. In keeping with long-established practice in scintillation counting, a compromise concentration (4 gm/l) was chosen which conserved on the quantity of primary solute with very little sacrifice in pulse height.

Measurements were first carried out with solutions containing 4 gm/l *p*-terphenyl in toluene and a secondary solute at concentrations from 10^{-5} to 1 gm/l. Relative pulse heights with tube "S-4" are shown in Fig. 1. It is not until 10^{-3} gm/l that the pulse heights start to rise above the *p*-terphenyl value. With the exception of DPH, the curves continue to rise up to the concentration, 1 gm/l. For the curve to rise at all, some energy transfer must have taken place. Energy loss during transfer is offset by improvement in spectrum. The curve for DPH starts to drop at 0.1 gm/l, showing a serious degree of self-quenching. POPOP is best, followed by αNPO. At 0.1 gm/l, PPO is slightly superior to DPH.

Figure 2 shows results with the same solutions as in Fig. 1, the one change in conditions being use of the photomultiplier "S-9." This tube made *p*-terphenyl look worse than before and made the secondary solutes with long wavelength spectra look even better. This was consistent with the different spectral sensitivities of these photomultipliers. The greatest relative change occurred for DPH whose long wavelength spectrum allowed it to be quite superior to PPO at 0.1 gm/l. POPOP retained its position as best in this group of four. By comparing POPOP in Figs. 1 and 2 at 0.1 and 10^{-5} gm/l, one can calculate the "spectral sensitivity index" alluded to previously. This is 2.26 for tube "S-9" and 1.72 for tube "S-4."

It seemed desirable to find out what would happen when PPO, an efficient primary solute, was made to replace *p*-terphenyl in double-solute systems with the same four compounds already used. Figure 3 shows the results with tube "S-4" and suggests that less efficient energy transfer occurs from PPO than from *p*-terphenyl. It is interesting to further note here that the most efficient primary solute, PBD (*2*), gives greater pulse height alone than combined with POPOP at 0.1 gm/l. It can be inferred that this represents a case of energy transfer wherein the benefit of photon emission at longer wavelengths does not compensate for the inefficiency of the energy transfer process.

Secondary-solute Pulse-height Data

*Secondary Solute**	*Relative† pulse height*	*Relative pulse-height reflector ratio (TiO_2/Al)*
1,4-di-[2-(5-phenyloxazolyl)]-benzene (POPOP)	1.45	1.19
2,5-di-(4-biphenylyl)-oxazole (BBO)	1.44	1.16
2,2′-bi-[5-(2-naphthyl)-oxazolyl]	1.37	1.19
2-(1-naphthyl)-5-(4-biphenylyl)-oxazole	1.34	1.12
2,5-di-(2-naphthyl)-oxazole	1.33	1.13
2,2′-bi-(5-phenyloxazolyl)	1.33	1.17
2-(1-naphthyl)-5-(2-naphthyl)-oxazole	1.31	1.16
1,4-di-[2-[5-(4-biphenylyl)-oxazolyl]]-benzene	1.31	1.21
2-(4-biphenylyl)-5-phenyloxazole	1.28	1.06
2-(4-biphenylyl)-indole	1.28	1.08
2,5-di-(1-naphthyl)-oxazole	1.28	1.14
2-phenyl-5-(4-biphenylyl)-oxazole	1.26	1.07
2-(4-methoxyphenyl)-5-(4-biphenylyl)-oxazole	1.24	1.05
2-(2-naphthyl)-5-phenyloxazole	1.22	1.04
2-(4-methoxyphenyl)-5-(2-naphthyl)-oxazole	1.22	1.04
2-(1-naphthyl)-5-phenyloxazole (αNPO)	1.21	1.11
2-phenyl-5-(2-naphthyl)-oxazole	1.18	1.04
2,5-di-(1-naphthyl)-1,3,4-oxadiazole	1.11	1.02
2-phenyl-5-(1-naphthyl)-oxazole	1.11	1.03
2-(ω-styryl)-5-phenyloxazole	1.01	1.20
2,5-diphenyloxazole (PPO)	0.97	0.95
1,6-diphenyl-1,3,5-hexatriene (DPH)	0.94	1.19
p-terphenyl	0.76	0.84
1,1,4,4-tetraphenyl-1,3-butadiene	0.20	1.11

* At 0.1 g/l with 4 g/l p-terphenyl.
† Relative to that obtained with 3 gm/l PPO in toluene.

New Secondary Solutes

A group of compounds was chosen from an earlier primary-solute study (*2*) using the criteria of high TiO_2/Al ratio and large relative pulse height. Solutions were made of these compounds at 0.1 gm/l containing also 4 gm/l *p*-terphenyl. Relative pulse heights were run with a TiO_2 reflector and a DuMont 6292 photomultiplier having "average spectral characteristics." The results are given in the table on p. 44, including those of POPOP, αNPO, PPO, and DPH. The compounds are arranged in order of decreasing pulse height. The reflector ratios in the last column, serve as indications of the mean wavelength of emitted light.

Large-Detector Study

The greatest use of secondary solutes is in providing photons of longer wavelength and, consequently, larger mean free path in large liquid-scintillation detectors. The order and magnitude of relative pulse heights recorded here, obtained from a solution geometry with essentially zero path length, might not remain the same in a large detector. Two compounds with the same relative pulse heights but with different mean wavelengths of emission would be expected to give increasingly different responses with longer required photon path lengths. Thus, it seemed necessary to prepare a few of these solutions on a large scale and make pulse-height measurements with them in a big detector.

Four scintillator solutions of about 60 l were prepared with 4 gm/l *p*-terphenyl and 0.1 gm/l of each of the following secondary solutes in toluene,

namely, POPOP, BBO, αNPO and DPH. A fifth solution was 4 gm/l *p*-terphenyl in toluene with no added secondary solute.

These solutions were tested in a detector holding a little less than 60 l. The detector had an internal TiO_2 reflector and about four per cent of its inner surface was photosensitive through the use of thirty-two DuMont 6292 photomultipliers. It was found necessary to rinse the detector thoroughly with toluene between solutions.

Pulse spectra from the 4.43-Mev gamma ray of excited C^{12} and the 2.76-Mev gamma ray of Na^{24} were analyzed and the peak discriminator setting was used as measurement of solution pulse height. A further diversification of conditions was obtained by using both air and argon as the dissolved gas in the scintillator.

The relative pulse height results were averaged and found to contain uncertainties of about ±5 per cent. The average values, normalized to give POPOP the same number as in the table on p. 44, are:

POPOP	1.45
BBO	1.41
αNPO	1.19
DPH	1.03
p-terphenyl	0.26

The first three values are not statistically different from those in the previous table. DPH has shown a slight increase and *p*-terphenyl has taken a serious drop. These last two results seem consistent with what is known of the spectra of these compounds (*6, 8*). The mean wavelength of the DPH spectrum is probably the longest of all these substances. This allows a greater fraction of the DPH photons to reach the photomultipliers. On the other hand, *p*-terphenyl has the shortest average wavelength, and a large fraction of the emitted photons are lost in the reflector or absorbed in the scintillator.

In all, it seems that the small-volume relative pulse height with a TiO_2 reflector is a good indication of relative usefulness of secondary solutes in large-volume detectors. Serious disagreements will occur only when mean wavelengths are significantly different from each other. Long wavelength, until it becomes too long for a good match with the photocathode, will enhance the pulse height through better light transmission; short wavelength will be detrimental because of poorer transmission, reflection and photoelectric conversion.

Other results obtained from this study gave an indication of the pulse-height linearity of a large liquid scintillation detector for gammas of 2.5–4.5 Mev. The ratio of the energies of the two gammas used is 1.6. The average experimental ratio was 1.7 ± 0.1.

Another interesting number arising from these large-volume detector experiments was the average oxygen-quenching factor. This value proved to be 0.78 ± 0.05, which is in reasonable agreement with previous Los Alamos numbers of about 0.82 (*5*).

Conclusions

This study should properly serve not only as a survey of secondary solutes but also as a useful guide to one who would choose an efficient liquid scintillator. Certain practical conclusions can be drawn.

1. A double-solute liquid scintillator is capable of yielding a better combination of wavelength and pulse height than a single-solute system. This makes it slightly preferable in small-volume counters and immensely superior in large-volume detectors.

2. The best secondary solutes are 1,4-di-[2-(5-phenyloxazolyl)]-benzene (POPOP) and 2,5-di-(4-biphenylyl)-oxazole (BBO).

3. *p*-terphenyl is an excellent primary solute in conjunction with POPOP or BBO.

4. The concentration range 0.05–0.5 gm/l seems to be preferable for POPOP and BBO. The commonly required compromise between economy and response suggests the choice of 0.1 gm./l. Similar reasoning suggests 4 gm/l as a good primary-solute concentration.

The results of a related study of the relative pulse heights from the most notable organic scintillators including plastic and crystal types are given in the table on this page.

* * *

This work was done under the auspices of the U. S. Atomic Energy Commission.

Pulse Height Comparisons of Most-Notable Organic Scintillators*

Solvent	*Primary solute (concentration in gm/l)*	*Secondary solute (concentration in gm/l)*	*Relative pulse height*
Liquid			
Toluene	PPO (3)		1.00[a]
Toluene	*p*-terphenyl (4)	POPOP (0.1)	1.22[a]
Toluene	PBD (10)		1.28[a]
p-Xylene	PBD (10)		1.40[a]
Plastic			
Polyvinyltoluene[b]	*p*-terphenyl (36)	POPOP (1)	1.02
Polyvinyltoluene[c]	*p*-terphenyl (36)	4,4′-diphenylstilbene (0.9)	1.04
Crystal			
trans-Stilbene[d,e]			1.56
Anthracene[d,f]			1.99

* Conditions: 1. Volume, 1 ml (cylinder: 0.3 in. ht. × 0.5 in. diam.) 2. Aluminum reflector. 3. DuMont 6292 photomultiplier with "average spectral characteristics."

[a] Dissolved air replaced by argon

[b] Experimental sample from Pilot Chemicals, Inc., Waltham, Mass.

[c] Prepared by Warren L. Buck, Argonne National Laboratory, Lemont, Ill.

[d] Best of four commercial products from two manufacturers

[e] Poorest sample gave 1.48

[f] Poorest sample gave 1.68

BIBLIOGRAPHY

1. F. N. Hayes, B. S. Rogers, D. G. Ott, *J. Am. Chem. Soc.* **77,** 1850 (1955)
2. F. N. Hayes, D. G. Ott, V. N. Kerr, B. S. Rogers, NUCLEONICS **13,** No. 12, 38 (1955)
3. C. L. Cowan, Jr., F. Reines, F. B. Harrison, E. C. Anderson, F. N. Hayes, *Phys. Rev.* **90,** 493 (1953)
4. M. A. Van Dilla, R. L. Schuch, E. C. Anderson, NUCLEONICS **13,** No. 9, 22 (1954)
5. D. G. Ott, F. N. Hayes, J. E. Hammel, J. F. Kephart, NUCLEONICS **13,** No. 5, 62 (1955)
6. H. Kallman, M. Furst, *Phys. Rev.* **81,** 853 (1951)
7. R. W. Pringle, B. L. Funt, L. D. Black, S. Sobering, *Phys. Rev.* **92,** 1582 (1953)
8. F. X. Roser, *Science* **121,** 806 (1955)

How to Calculate Gamma Radiation Induced in Reactor Materials

Gamma activity induced in engineering materials, under conditions similar to those in the ORNL graphite reactor, can be estimated with this data. Thin specimens were irradiated in the reactor and component activities determined

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MEASUREMENTS WERE MADE of the gamma activity induced in a number of structural and reactor materials that were irradiated in the ORNL Graphite Reactor (*1*). From these data, a reasonably good estimate can be made of the activity induced in materials that are exposed under similar conditions. Table 1 has been constructed for this purpose.*

Table 1 is directly applicable to reactors of the same general class as the ORNL Graphite Reactor. For other types of reactors, one should recognize two limitations:

1. The neutron flux in the Graphite Reactor is low enough so that only for very-high-cross-section materials is depletion of the parent element significant, except for extremely long irradiation periods.

2. Activation in the ORNL Graphite Reactor is primarily by thermal neutrons. If materials are exposed to a higher ratio of fast-to-thermal neutrons (*2*), (n,p) and (n,α) reactions—often more predominant with fast neutrons—are likely to give relatively greater contribution.

Basis for Table

The rate of change in the number of radioactive atoms per gram of material when burn-up of the parent element may be neglected, is given approximately by

$$dn/dt = \phi\sigma N - n\lambda \qquad (1)$$

and the number of radioactive atoms present is

$$n = (\phi\sigma N/\lambda)\,(1 - e^{-\lambda t})$$

where n = number of radioactive atoms (atoms/gm), ϕ = neutron flux, (neutrons/cm²/sec), N = number of

* The alternative method of estimating the activity is to calculate it from the chemical composition of the material and the neutron cross section values from the literature (*3*, *4*). Except in the cases noted, activities calculated by the two methods are in good agreement.

TABLE 1—Induced Gamma

		Component 1	
Material	$t_{1/2}$	Σ_x* (cm²/gm)	E_x† (Mev)
Iron alloys			
Armco Iron	2.5h	8×10^{-5}	1.15
Duriron	2.5h	1.2×10^{-3}	1.15
1015	2.5h	1.4×10^{-3}	1.15
1030	2.5h	1.4×10^{-3}	1.15
1045	2.5h	1.7×10^{-3}	1.15
6150	2.5h	1.4×10^{-3}	1.15
Nickel alloys			
Nickel	2.5h	2×10^{-5}	1
Hastelloy A	2.5h	1.0×10^{-3}	1.15
Hastelloy B	2.5h	1.4×10^{-3}	1.15
Hastelloy C	2.5h	3.4×10^{-3}	1.15
Hastelloy D	2.5h	1.4×10^{-3}	1.15
Inconel	2.5h	3.3×10^{-4}	1.15
Inconel X	2.5h	6×10^{-4}	1.15
K Monel	2.5h	2×10^{-3}	1.15
Stainless steels			
Carpenter 20	2.5h	1.6×10^{-3}	1.15
302	2.5h	1.3×10^{-3}	1.15
303	2.5h	8×10^{-4}	1.15
304	2.5h	8×10^{-4}	1.15
309	2.5h	3×10^{-3}	1.15
310	2.5h	3×10^{-3}	1.15
316	2.5h	3.3×10^{-3}	1.15
317	2.5h	4.2×10^{-3}	1.15
347	2.5h	3×10^{-3}	1.15
405	2.5h	1.0×10^{-3}	1.15
410	2.5h	9.3×10^{-4}	1.15
414	2.5h	9.3×10^{-4}	1.15
430	2.5h	7×10^{-4}	1.15
431	2.5h	1.0×10^{-3}	1.15
446	2.5h	1.1×10^{-3}	1.15
502	2.5h	4.3×10^{-4}	1.15
Aluminum alloys			
28	2.5h	2×10^{-4}	1.15
38	2.5h	1.2×10^{-3}	1.15
528	2.5h	6×10^{-5}	1.15
728	2.5h	$<10^{-5}$	1.15

Identity of the Component Activities

IRON ALLOYS

The 2.5 hour component may be due both to the $Fe^{58}(n,p)Mn^{58}$ and the $Mn^{55}(n,\gamma)Mn^{56}$ reactions. An upper limit on the (n,p) reaction is fixed by the lowest value of this component measured for any of the iron alloys—that for Armco iron. The high values for the other iron alloys are due to their manganese content.

The 46-day component checks closely for all the iron alloys and is 50% higher than the value calculated for the $Fe^{58}(n,\gamma)$ reaction. This difference may be due to error introduced by the use of the thermal neutron cross section as an approximation for neutrons with the energy distribution that is present in the reactor.

Activity in Some Common Structural Materials

Component 2			Component 3			Component 4			Component 5		
$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)	$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)	$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)	$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)
45d	3.1×10^{-5}	1.2	5.3y	5.0×10^{-5}	1.25						
45d	2.6×10^{-5}	1.2	5.3y	6.4×10^{-5}	1.25						
45d	3.3×10^{-5}	1.2	5.3y	4.6×10^{-5}	1.25						
45d	3.3×10^{-5}	1.2	5.3y	4.6×10^{-5}	1.25						
45d	3.3×10^{-5}	1.2	5.3y	7.9×10^{-5}	1.25						
45d	3.3×10^{-5}	1.2	5.3y	4.6×10^{-5}	1.25						
60d	4×10^{-5}	0.8	5.3y	8.0×10^{-4}	1.25						
60h	1.8×10^{-4}	0.3	60d	3×10^{-5}	1	5.3y	3.6×10^{-3}	1.25			
60h	1.5×10^{-4}	0.3	60d	2.2×10^{-5}	1	5.3y	2.7×10^{-3}	1.25			
60h	6×10^{-5}	0.3	25d	8.5×10^{-5}	0.32	60d	1×10^{-4}	1	5.3y	9.5×10^{-4}	1.25
13h	5.2×10^{-4}	0.51	60d	3.9×10^{-5}	1.2	5.3y	3.9×10^{-3}	1.25			
25d	4.1×10^{-5}	0.32	60d	4.3×10^{-5}	1.2	5.3y	7.4×10^{-4}	1.25			
25d	5×10^{-5}	0.32	60d	5.0×10^{-5}	1.2	115d	9.2×10^{-5}	1.2	5.3y	7×10^{-4}	1.25
13h	2.7×10^{-3}	0.51	60d	2.7×10^{-5}	1.2	5.3y	2.1×10^{-3}	1.25			
15h	2.4×10^{-4}	0.51	25d	5.5×10^{-5}	0.32	45d	3.9×10^{-5}	1.2	5.3y	1.2×10^{-3}	1.25
25d	7.4×10^{-5}	0.32	45d	3.6×10^{-5}	1.2	5.3y	6.2×10^{-4}	1.25			
25d	7.4×10^{-5}	0.32	45d	3.6×10^{-5}	1.2	5.3y	6.0×10^{-4}	1.25			
25d	5.5×10^{-5}	0.32	45d	3.6×10^{-5}	1.2	5.3y	5.0×10^{-4}	1.25			
25d	8.2×10^{-5}	0.32	45d	3.6×10^{-5}	1.2	120d	3.5×10^{-5}	1.2	5.3y	8.3×10^{-4}	1.25
25d	9.8×10^{-5}	0.32	45d	3.8×10^{-5}	1.2	5.3y	1.1×10^{-3}	1.25			
25d	8.5×10^{-5}	0.32	45d	3.3×10^{-5}	1.2	5.3y	7.3×10^{-4}	1.25			
25d	9.6×10^{-5}	0.32	45d	3.6×10^{-5}	1.2	5.3y	9.5×10^{-4}	1.25			
25d	9.6×10^{-5}	0.32	45d	2.7×10^{-5}	1.2	120d	2.9×10^{-5}	1.2	5.3y	6.1×10^{-4}	1.25
25d	6.6×10^{-5}	0.32	45d	3.2×10^{-5}	1.2	5.3y	1.4×10^{-4}	1.25			
25d	5.5×10^{-5}	0.32	45d	3.5×10^{-5}	1.2	5.3y	1.3×10^{-4}	1.25			
25d	5.5×10^{-5}	0.32	45d	3.2×10^{-5}	1.2	5.3y	1.9×10^{-4}	1.25			
25d	7.3×10^{-5}	0.32	45d	2.7×10^{-5}	1.2	5.3y	1.1×10^{-4}	1.25			
25d	5.7×10^{-5}	0.32	45d	3.5×10^{-5}	1.2	5.3y	2.1×10^{-4}	1.25			
25d	1.2×10^{-4}	0.32	45d	2.5×10^{-5}	1.2	5.3y	1.4×10^{-4}	1.25			
25d	1.6×10^{-5}	0.32	45d	3.2×10^{-5}	1.2	5.3y	6.0×10^{-5}	1.25			
15h	8.4×10^{-6}	2.07	130d	1.1×10^{-7}	1.2	5.3y	5×10^{-7}	1.25			
15h	5.7×10^{-6}	2.07	45d	2.1×10^{-7}	1.2	5.3y	1.4×10^{-6}	1.25			
15h	5.7×10^{-6}	2.07	120d	1.4×10^{-7}	1.2	5.3y	4×10^{-7}	1.25			
15h	9.8×10^{-6}	2.07	250d	1.3×10^{-5}	1.12						

The activity component remaining after subtracting the shorter lived components was taken as 5.3-year Co^{60} and is accounted for by a cobalt content of 0.01 to 0.05% for the various alloys. In 410 and 400 stainless steels the presence of enough cobalt to account for the 5.3-year activity was confirmed by chemical analysis. This identity agrees with the average energy of the gamma radiation, about 1.0 to 1.2 Mev.

NICKEL ALLOYS

Since the 2.5-hour component was only about 10% of the total activity of the nickel sample at the time decay measurements were begun, the accuracy of resolution of this component is not better than 50%. This measured activity, from Ni^{64} $(n,\gamma)Ni^{65}$, did not check the calculated activity—the calculated value being about 3 times too large. The 2.5-hour activity for the nickel alloys is from Mn^{56}.

The 60–70 day component is probably from the Ni^{58} $(n,p)Co^{58}$ reaction. After 27 hours decay time the ion chamber response for the nickel sample is about 40% from the 60–70 day Co^{58} and 60% from the 5.3-year Co^{60}. The average value of gamma energy is 1.25 Mev for Co^{60} and 0.80 Mev for Co^{58}; this gives an average energy for the nickel of $0.4 \times 0.80 + 0.6 \times 1.25 = 1.07$ Mev, in good agreement with the value from absorption measurements, 1.1 ± 0.1 Mev.

Other activities are due to 26.5-day Cr^{51}, 67-hour Mo^{99}, and 12.8-hr Cu^{64}. The 46-day Fe^{59} activity is not resolvable from the 60–70-day Co^{58} in the 60-day component by the present analysis, therefore the two are combined in Table 1.

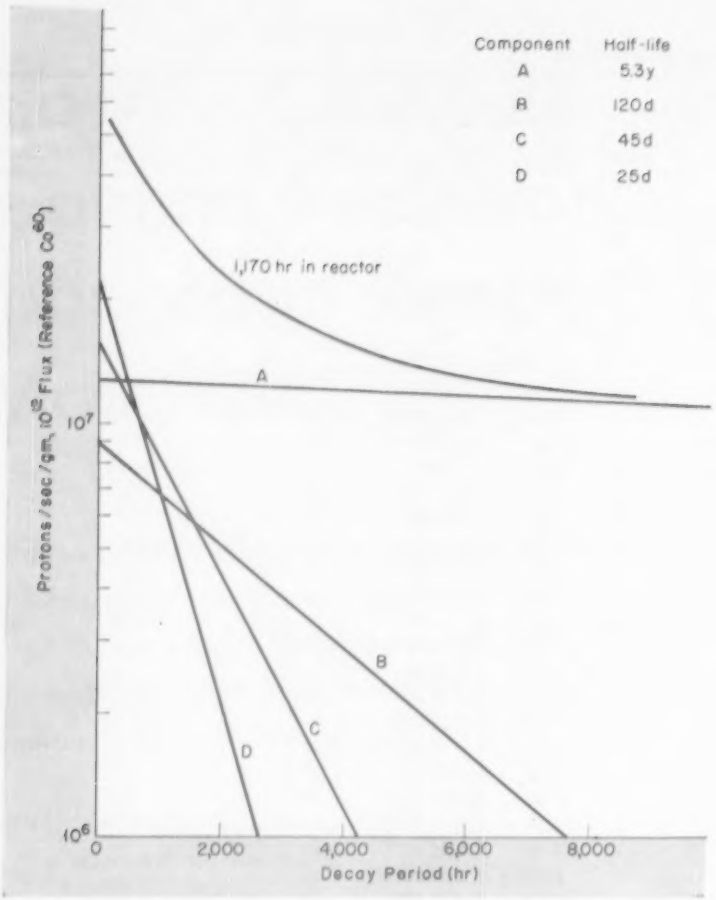
STAINLESS STEELS

The 2.5-hour activity is 2.59-hour Mn^{56}, the 46-day activity to 46-day Fe^{59}, and the 5.3-year activity is Co^{60} as discussed for the iron and nickel alloys. The 25-day activity is due to 26.5-day Cr^{51}. The 120-day activity is due to 113-day Ta^{182} from the tantalum present in the niobium stabilizer in the 309 and 347 alloys.

ALUMINUM ALLOYS

The 2.5-hour activity is from Mn. The 15-hour component is due to the Al^{27} $(n,\alpha)Na^{24}$ reaction. The 250-day Zn^{65} activity in 728 aluminum agrees with the calculated value based on 1% Zn. The 45-day component in 38 aluminum may be accounted for by about 0.5% iron. 5 ppm tantalum and 1 ppm cobalt may account for the other activities.

(Continued on p. 48)



ANALYSIS of decay curve for 347 stainless steel. The 2.5-hr component shown in Table 1 was determined by an expanded plot of the first 40 hr decay

(Table 1 continued)

	Component 1		
Material	$t_{1/2}$	Σ_s* (cm²/gm)	E_γ† (Mev)
Other metals			
Beryllium	2.5h	7.5×10^{-6}	1.15
Cadmium	60h	5.2×10^{-4}	0.40
Copper	2.5h	1×10^{-5}	1.15
Lead	2.5h	$<10^{-7}$	1.15
Niobium	115d	6.6×10^{-4}	1.2
Titanium	2.5h	4.7×10^{-5}	1.15
Thorium	27d	7.4×10^{-3}	0.3
Ferro-tungsten	2.5h	1.4×10^{-3}	1.15
Zirconium	2.5h	2.8×10^{-4}	1.15
Concrete			
Barytes Concrete	2.5h	9.5×10^{-5}	1.15
Brookhaven Cement	2.5h	9.5×10^{-4}	1.15
Portland Concrete	2.5h	9.5×10^{-5}	1.15
Graphite			
GBF	15h	2.7×10^{-8}	2.07
CS	15h	3.4×10^{-8}	2.07
C-18	15h	4.7×10^{-7}	2.07

BERYLLIUM

From typical Be analyses it is deduced that the 80-day component is a combination of the activities induced in Zn, Fe and Ni. It is difficult to resolve this portion of the curve due to the large 5.3-year component from Co^{60}.

CADMIUM

The 60-hour component, due to 58-hour Cd^{115} is less than $\frac{1}{2}$ the calculated value and is likely due to a flux depression caused by the high cross section Cd^{113}. The 40-day component is likely 43-day Cd^{115}. The 250-day component is likely 250-day Zn^{65}.

COPPER

Since more than 95% of the photons from

parent isotope atoms (atoms/gm), σ = isotopic activation cross section (cm²), $\lambda = 0.693/t_{1/2}$, $t_{1/2}$ = half-life (sec), and t = irradiation time (sec).

The activity, in disintegrations per second per gram is

$$n\lambda = \phi\sigma N(1 - e^{-\lambda t})$$

and the specific activity a, in photons/sec per gram, is

$$a = \phi\sigma NX(1 - e^{-\lambda t})$$

where X = photons per disintegration.

It is convenient to define a macroscopic absorption cross section, Σ_s, such that $\Sigma_s = \sigma NX$ cm²/gm of material. Then

$$a = \phi\Sigma_s(1 - e^{-\lambda t}) \qquad (2)$$

Estimating Induced Activities

Measurements were made on small thin specimens so that no correction was required either for self-absorption or for depression of the neutron flux. One seldom has such ideal conditions in engineering applications. These corrections, which must not be neglected in the case of large thick specimens, will not be discussed here (for an idea of the correction, see references *4* and *5*).

Calculation. Where a period of decay ensues after reactor shutdown, the activity for each component radioactive element is given by

$$A = \phi\Sigma_s W(1 - e^{-\lambda t_1})e^{-\lambda t_2} \qquad (3)$$

where A = photons/sec, W = weight of specimen (gm), t_1 = irradiation time, t_2 = decay time, and ϕ, Σ_s, and λ are defined as previously.

Conversion to r/hr. Since the principal use for induced-activity calculations is for shielding, it is often desirable to convert the gamma flux to roentgen/hr. The gamma flux (photons/cm²/sec) is related to r/hr by the absorption coefficient of air for the gamma radiation, the energy of the radiation, and an energy conversion factor

$$\text{r/hr} = \theta EK\mu \qquad (4)$$

where θ = gamma flux (photons/cm²/sec), E = energy of the photon (Mev) K = conversion factor = 0.053 (r, cm², sec)/(Mev, hr) = 1.48×10^{-5} r, cm²/Mev × 3,600 sec/hr, and μ = absorption coefficient = about 3.5×10^{-5} cm⁻¹ for photon energies from 0.5 to 2 Mev.

E_γ from Table 1 can be used for the energy in this calculation. This is an

Component 2			Component 3			Component 4			Component 5		
$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)	$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)	$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)	$t_{1/2}$	Σ_x (cm^2/gm)	E_x (Mev)
80d	1.1×10^{-6}	1	5.3y	1.7×10^{-6}	1.25						
40d	2.5×10^{-6}	0.9	250d	1.6×10^{-6}	1.12						
13h	7.2×10^{-3}	0.51	100d	2×10^{-6}	1.1						
50h	3.5×10^{-7}	1.2	140d	5.6×10^{-7}	1.2						
35h	2.3×10^{-6}	1.1	80d	1.4×10^{-6}	1.0						
20h	3.2×10^{-5}	0.5	45d	3.2×10^{-5}	1.2	5.3y	2.8×10^{-6}	1.25			
20h	1.0×10^{-4}	0.7	60d	4.8×10^{-4}	0.74						
12d	1.3×10^{-5}	0.9	60d	2.7×10^{-6}	1.2	250d	1.9×10^{-6}	1.12	5.3y	4.4×10^{-6}	1.25
15h	1.7×10^{-5}	2.07	50d	1.4×10^{-5}	1.2	250d	1.6×10^{-6}	1.12	5.3y	1.3×10^{-5}	1.25
15h	5.8×10^{-5}	2.07	12d	9.7×10^{-7}	0.9	85d	2.0×10^{-6}	1	5.3y	4.4×10^{-6}	1.25
100d	8×10^{-10}	1	5.3y	1.1×10^{-5}	1.25						
35h	1.4×10^{-5}	1	85d	1.6×10^{-5}	1	5.3y	4.4×10^{-6}	1.25			
70d	1.3×10^{-7}	1	5.3y	7.3×10^{-7}	1.25						

12.9-hr Cu^{64} result from positron annihilation, the others are neglected in the analysis and the energy taken as 0.51 Mev. The Mn^{56} component is quite strong in this material. The energy of the 100-day component was determined from absorption measurements.

LEAD

The induced activity is relatively low. The 2.5-hr component is likely Mn^{56}; the 50-hr component was not identified; the 140-day component is likely Ta^{182}.

NIOBIUM

The greater part of the activity is accounted for by a tantalum content of 1.2%.

TITANIUM

Manganese likely contributes the short-lived activity. The 35-hour component may result from the reaction Ti^{48} $(n,p)Sc^{48}$. The 80-day component is likely 85-day Sc^{46} from the reaction Ti^{46} $(n,p)Sc^{46}$.

THORIUM

The greater part of the activity is 27-day Pa^{233}.

FERRO-TUNGSTEN

The components are 2.5-hour Mn^{56}, 24-hour W^{187}, 46-day Fe^{59}, and 5.3-year Co^{60}.

ZIRCONIUM

The components are 2.5-hour Mn^{56}, 17-hour Zr^{97}, and 65-day Zr^{95}.

CONCRETE

The components are 2.5-hour Mn^{56}, 14.8-hour Na^{24}, 12.8-day Ba^{140}, 46-day Fe^{59} (which is included in the 50–60 day component), 250-day Zn^{65}, and 5.3-year Co^{60}. The 85-day component was not identified. The 60-day, 140-day and 250-day components agree respectively with calculated values for Fe, Ba and Zn for these materials.

GRAPHITE

The 15-hour component is likely 14.8-hour Na^{24}. The 35-hour and 70–100-day components are probably mixtures of several components. The 5.3-year component is likely Co^{60}.

* Σ_x = the cross section that gives the total number of photons of all energies.

† E_x = the average of the products of the energy of the photon and the number of photons of that energy that are emitted. (This figure is included for use in approximate shielding calculations.)

Sample Calculation of Induced Gamma Activity

A 5-gm thin foil of Inconel has been in the reactor for 30 days at a flux of 10^{13} n/cm²/sec. How much gamma radiation will this specimen emit 24 hr after reactor shutdown?

Substituting values from Table 1 in Eq. 3

Component 1 (2.5-hr half-life)

$$A = (10^{12})(3.3 \times 10^{-4})(5)(1 - e^{-\frac{0.693 \times 30 \times 24}{2.5}})e^{-\frac{0.693 \times 24}{2.5}}$$
$$= 1.7 \times 10^{6} \text{ photons/sec}$$

Component 2 (25-day half-life)

$$A = (10^{12})(4.1 \times 10^{-5})(5)(1 - e^{-\frac{0.693 \times 30}{25}})e^{-\frac{-0.693 \times 1}{25}}$$
$$= 1.1 \times 10^{8} \text{ photons/sec}$$

Component 3 (60-day half-life)

$$A = (10^{12})(4.3 \times 10^{-5})(5)(1 - e^{-\frac{0.693 \times 30}{60}})e^{-\frac{-0.693 \times 1}{60}}$$
$$= 6.2 \times 10^{7} \text{ photons/sec}$$

Component 4 (5.3-yr half-life)

$$A = (10^{12})(7.4 \times 10^{-4})(5)(1 - e^{-\frac{0.693 \times 30}{5.3 \times 365}})e^{-\frac{-0.693 \times 1}{5.3 \times 365}}$$
$$= 4.0 \times 10^{7} \text{ photons/sec}$$

Conversion to r/hr

Convert component 3 of the above example to r/hr at 10 cm.

Here a simple configuration is assumed—a point source. The area over which the photons are distributed is $4\pi r^2$. The photon flux at 10 cm is then

$$\frac{6.2 \times 10^{7}}{4 \times 3.14 \times 10^{2}} = 4.9 \times 10^{4} \text{ photon/cm}^2\text{/sec}$$

Substituting in Eq. 4

$$r/hr = (4.9 \times 10^{4})(1.2)(0.053)(3.5 \times 10^{-5}) = 0.11$$

average energy that was determined by the decay scheme (*3, 4*) of the isotope or (if the isotope was not identified) was estimated by an absorption measurement. For greater accuracy one should, of course, make a separate calculation for each individual gamma-ray energy. In Table 2 the pertinent isotopes are listed with their photon energies and yields (*4*). The number of photons per disintegration is also listed.

Experimental

Specimens were prepared by cutting chips or shavings small enough to have negligible self-absorption. Irradiations were made in the ORNL Graphite Reactor for periods from 150 to 15,000 hr.

Upon removal from the reactor, the decay of gamma activity was followed with a high-pressure ionization chamber (*6*) (Fig. 1) until the remaining activity had a half-life greater than a year. The decay of some materials was recorded for over 20,000 hr—most for at least 8,000 hr. Interest here is centered on the long-lived isotopes, and measurements were not begun until 3 or 4 hr after reactor shutdown.

To assist in establishing the average energy of the radiations, absorption measurements (*1*) were made during the decay period by interposing sheets of lead between the specimen and a G-M tube.

Decay curves for the irradiated materials (*1*) were analyzed into component activities, as shown in the illustration. The identities of most of the component activities—and therefore their average energies—can be established from their half-lives and chemical analysis of the materials. Activity, a, was then calculated from the calibration of the ionization chamber (*6*). If the component was not identified, the photon energy was estimated by absorption measurements. The absorption cross section Σ_a was calculated using Eq. 2. (The reactor flux was taken from reference 7.)

TABLE 2—Photon Yield and Energy for Isotopes of Table 1

Isotope	*Half-life*	*Photon energies (Mev)*	*Disintegrations yielding a photon (%)*	*Photons* per disintegration (X)*	*Average energy,* Mev (E_λ)*
Na^{24}	14.8h	1.38	100	2.00	2.07
		2.75	100		
Sc^{46}	85d	0.88	100	2.00	1.00
		1.12	100		
Sc^{48}	44h	1.33	100	3.00	1.10
		0.98	100		
		1.00	100		
Cr^{51}	26.5d	0.32	8	0.08	0.32
Mn^{56}	2.59h	0.84	100	1.40	1.15
		1.81	25		
		2.13	15		
Co^{58}	72d	0.81	~100	~1	0.8
Fe^{59}	46d	1.10	50	1.00	1.20
		1.30	50		
Co^{60}	5.3y	1.17	100	2.00	1.25
		1.33	100		
Ni^{65}	2.56h	1.01	14	0.14	1
		1.49	?		
Cu^{64}	12.9h	0.51	37	0.37	0.51
Zn^{65}	250d	1.12	45	0.45	1.12
Zr^{95}-Nb^{95}	65d†	0.75	100	2.00	0.74
		0.72	99		
		0.23	1		
Zr^{97}	17h	0.75	100	2.00	0.71
		0.67	100		
Mo^{99}	67h	0.14	10	1.2	0.3
		0.18	90		
		0.37	?		
		0.74	10		
		0.78	10		
Cd^{115}	58h	0.34	58	1.42	0.40
		0.36	42		
		0.52	42		
Cd^{115}	43d	1.30	(2)?	1.6	0.9
		0.95	94		
		0.48	12		
Ba^{140}-La^{140}	12.8d†	2.9	(6)?	2.4	0.9
		2.51	5		
		1.60	95		
		0.82	4		
		0.52	51		
		0.32	11		
		0.16	70		
		0.09	5		
		0.03	100		
Ta^{182}	113d	1.13	37	0.94	1.19
		1.22	57		
W^{187}	24h	0.69	48	1.1	0.5
		0.55	8		
		0.48	25		
		0.13	8		
		0.21	25		
		†	?		
Pa^{233}	27d	0.40	70	1.00	0.30
		0.08	30		

* Photons of very low energy are omitted.
† Rate-determining half-life for the mother-daughter combination.

BIBLIOGRAPHY

1. C. D. Bopp, ORNL-1371 (1953)
2. C. D. Bopp, O. Sisman, ORNL-525 (1950)
3. K. Way, *et al.*, Circular 499 (National Bureau of Standards, U. S. Department of Commerce, Washington, D. C., 1950)
4. The Reactor Handbook, Vol. 1, Physics, AECD-3645 (1955)
5. J. S. Levin, D. J. Hughes, NUCLEONICS **11**, No. 7, 8 (1953)
6. J. W. Jones, R. T. Overman, MonC-399 (1948), AECD-2367
7. H. Jones, *et al.*, CP-2602 (1945)

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CROSS SECTIONS

Inexpensive Pulse Generator

By EUGENE T. PATRONIS, Jr.
School of Physics
Georgia Institute of Technology
Atlanta, Georgia

Pulse Characteristics

Repetition rate	—	20, 90, and 180/sec
Width	—	0.1–1μsec
Amplitude	—	0–11 or 0–1 volt
Polarity	—	+ or −

A reliable pulse generator that furnishes variable-width pulses of constant amplitude and selectable pulse-repetition rate is a practical necessity in a nuclear physics laboratory. The operations that depend upon such a generator include: alignment of coincidence and delay circuits, adjustment of pulse-height analyzers, maintenance of scaling equipment, and impedance matching of cables and equipment.

The pulse generator presented here (see circuit diagram) is versatile enough for the essential operations and can be constructed at a small cost. It consists essentially of four sections.

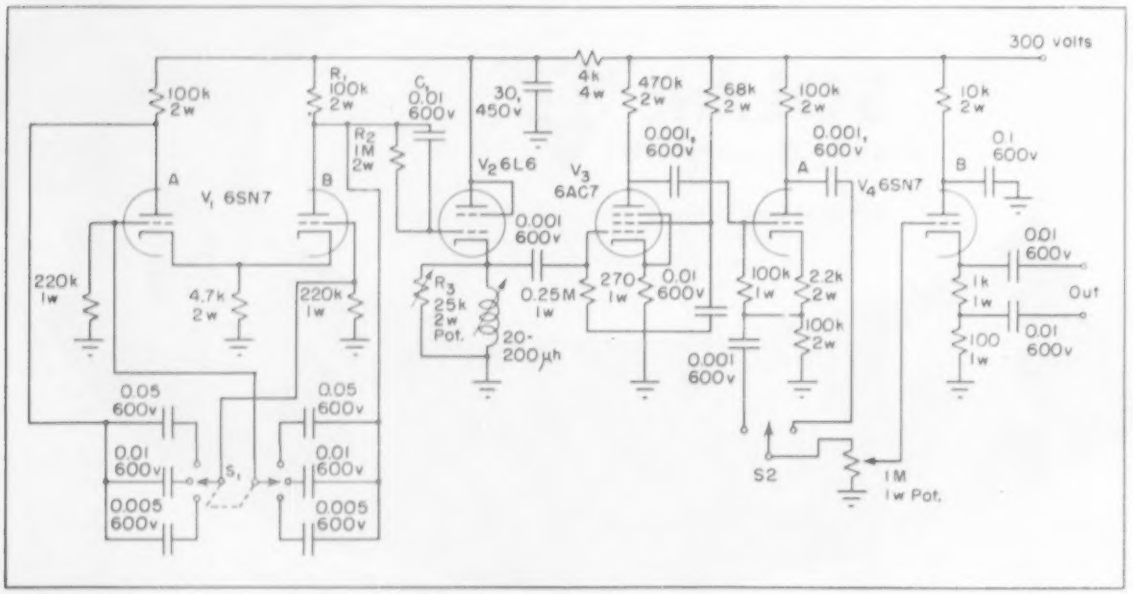
The first section is a symmetrical multivibrator employing a 6SN7 dual-triode, V_1. The coupling constants, changed by switch S_1, provide pulse-repetition rates of 20, 90, and 180/sec. The multivibrator output is directly coupled into V_2 by resistor R_2 and capacitor C.

V_2 comprises the second section of the pulse generator and is connected as a shock-excited oscillator. When V_{1B} is nonconducting, V_2 is conducting heavily since it is operating at very nearly zero bias. Most of the cathode current of V_2 is then carried by the variable inductor. When V_{1B} begins to conduct, V_2 is driven to cut-off by the large negative-going pulse that is developed across R_1. The resonant circuit in the cathode of V_2, which is composed of the variable inductor and its distributed capacity, is then shocked into oscillation.* The damping factor of the shock-excited oscillator is controlled by the variable resistance R_3. For a minimum pulse width with only a slight amount of overshoot, R_3 is adjusted so that the circuit is slightly underdamped. If the overshoot is undesirable, R_3 is adjusted so that the circuit is overdamped. This adjustment will bring about an increased pulse width however. The minimum pulse width obtainable will be sensitive to how the inductance is wound. In general, 0.1–1 μsec may be covered with the values given.

The third section of the pulse generator is an amplifier consisting of V_3 and V_4. A small amount of degeneration is introduced here by leaving the cathode of V_3 unbypassed. This improves the gain stability and bandpass of the amplifier. V_{4A} is a paraphase amplifier that furnishes an output of both polarities. Either a positive or negative pulse may be coupled into the final section of the generator by switch S_2.

The final section of the pulse generator is a cathode follower that furnishes a low source impedance for connection to cables, etc. For stable operation, a 300-volt d-c regulated power supply is required. An unregulated supply may be used with some sacrifice of stability.

* For a complete mathematical analysis, see J. D. Trimmer, "Response of Physical Systems" (John Wiley and Sons, Inc., New York, 1950).



PULSE GENERATOR is versatile enough for essential laboratory operations

Determining Concentration of Airborne Plutonium Dust

By G. W. C. TAIT
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Chalk River, Ontario, Canada

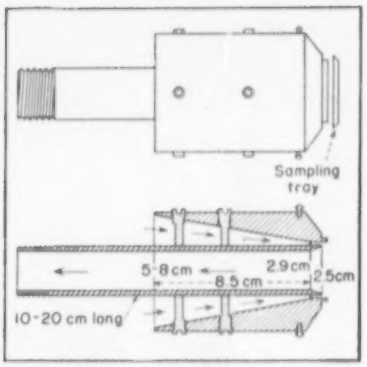
Natural radon-decay-product activity is often sufficient to completely mask more toxic airborne contaminants, such as a plutonium aerosol. The practice until now has been to sample the air with some filtering device and permit the active deposit to decay for an hour or more.

M. H. Wilkening* suggested a new approach. It was noted that radon-decay products in air are preferentially associated with the smaller dust particles with 90% of radon-decay-product activity on particles of less than 0.035-micron diameter. In contrast, if material is rendered airborne by mechanical disruption from the solid or liquid state, the bulk of the material is in the larger particle sizes with only a very small fraction less than 1-micron diameter. This is the condition that exists when α-emitting materials are handled.

As a result, any device that could separate airborne particles into two groups greater and less than 1-micron diameter would also provide a sample of active dust from plant spills substantially free from radon-decay products.

Impaction devices are available that make this separation. However, their sampling rates (up to 20 liters per minute of air) are not fast enough for rapid detection of highly toxic contaminants such as plutonium. It was therefore decided to design an annular impactor operating at a sampling rate of 500–1,000 l/min. The construction is shown in Fig. 1.

* M. H. Wilkening, *Rev. Sci. Instr.* **23**, 13 (1952).



ANNULAR IMPACTOR. Cone converges to cylinder with lip shaped to take sampling tray. Tray is retained with two studs that hold elastic band. Eight bolts center tube, which is threaded to fit adaptor for vacuum cleaner or other blower. Tube end adjacent to tray is adjusted to lie 0.25–0.35 cm from disk. Dimensions are not critical, but area of annulus should be adjusted to blower capacity to achieve jet velocity of 60–75 meters/sec

TABLE 1— Alpha Activity of Airborne Plutonium Samples

Trial	*Impactor disk (cpm/m³)*	*Filter parallel to impactor (cpm/m³)*	*Filter following impactor (cpm/m³)*	*Sampling efficiency (%)*
66	21	21	0.7	96
72	25	63	3.1	89
74	77	142	6.1	92
75	14	7.6	3.5	80
77	3.9	4.3	0.4	90
79	5.6	1.0	0.7	89
80	18	40	2.0	90

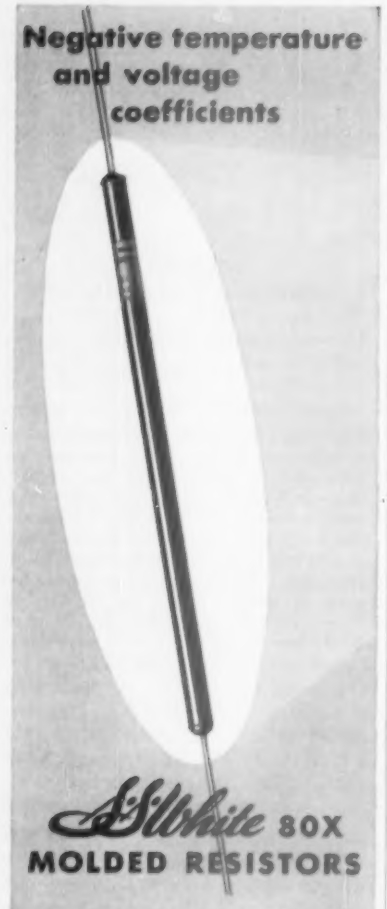
TABLE 2—Alpha Activity of Airborne Radon-Decay Products

Trial	*Delay between sampling and counting (min)*	*Impactor disk (cpm/m³)*	*Filter parallel to impactor (cpm/m³)*	*Filter following impactor (cpm/m³)*	*Sampling efficiency (%)*
48	15	1.7		29	6
49	20	1.7		15	10
50	15	1.9		26	7
51	25	1.4		17	8
70	25	0.2		2.4	8
81	17	7.3	39	31	19
82	28	3.8	50	38	9
83	20	0.7		52	1
84	19	1.1		12	8
85	20	0.4		6.3	6
86	18	0.7		11	6
87	13	3.9		59	6
88	20	1.2		18	6
89	15	7.1	80	65	11
90	33	2.4		16	13

Operation

A standard counting tray is lightly greased and put in place over the orifice of the impactor. The nature of the sticky material does not seem important, a thin layer of vaseline or silicone grease being acceptable. Air is drawn through the impactor for 2–5 min by means of a vacuum cleaner. The tray is then removed and counted with an alpha-sensitive scintillation counter.

The counter efficiency is slightly different than that for standard source trays. This results from the ringlike deposit close to the tray rim leading to



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a lower geometry than for standard sources well centered on the tray.

Once the counter efficiency has been determined, the activity of unit volume of air is readily found from the air flow rate for the sampling unit. The impactor possesses the advantage that the flow rate remains constant provided no change occurs in the efficiency of the blower. On the other hand, the flow rate of filter samplers is sensitive to the nature of the filter paper and changes with time as the pores of the paper become blocked.

Field Testing

The annular impactor was field tested where spills of plutonium had occurred. Comparisons were made with areas where it was known that radon-decay products were the chief alpha-emitting materials.

In the field trials the impactor was followed by a filter tube with air being drawn through at 700 l/min by two vacuum blowers in series. At the same time a single filter-tube sample was taken alongside by means of a third vacuum cleaner.

The counting efficiency for the sampling disks was found by counting in a scintillation counter of known efficiency. Filter-tube counting efficiency was found by equating the difference in count between the two filters in a run with the activity of the corresponding impactor disk. It is recognized that an error is introduced in assuming both filter tubes have the same counting efficiency since the particle sizes are different leading to different penetration into the paper. The error is not serious for the purpose of this investigation.

The degree of self-absorption within the impactor sample was considered. A microscopic examination of a number of annular deposits showed a range of thickness from 4 to 50 microns with a mean thickness of 8 microns. As this would be equivalent to about 2 cm of air, it is apparent that some self-absorption is likely to occur with these samples although the error introduced is not large.

Sampling Efficiency

Particle size counts were made of the slides from cascade impactors ahead of and following the annular impactor for dust of 2.3-gm/cm³ density. Results for various particle size ranges combined from all slides were used to calculate the efficiency of the annular impactor for various size groups.

The particle size for which half the particles pass the impactor is about 0.5 micron for a flow rate of 700 l/min.

Airborne Plutonium Dusts

A number of tubular-filter and annular-impactor samples were taken concurrently where it was expected that there was plutonium air contamination. Samples showing alpha counts are listed in Table 1.

In nearly all cases at least 24 hr delay occurred before counting to permit effective decay of radon daughters present. The impactor disks were counted with a scintillation counter that normally has an efficiency of 44%. However, tests showed a counting efficiency figure of 36% because of the annular form of deposits. No allowance is made for self-absorption. Provided the inert dust loading is not particularly high, this effect will not be excessive.

Table 1 shows considerable scatter in the relative counts shown by the impactor disk and the tubular filter run in parallel. This is not unexpected since the majority of the total count may be due to a few particles of relatively high activity. Taking the mean (geometric) of the individual ratios of such counts, however, gives a value close to unity, which suggests that the efficiency of the filter tubes may also be taken as 36% for this material. The sampling efficiency of the annular impactor is given by the ratio of the activity on the disk to the total for the disk plus the following filter tube. This ratio does not vary so erratically as that used to find the filter-tube counting efficiency. The average sampling efficiency using a considerably greater number of trials than those listed here is found to be 91% for the range of airborne Pu dusts encountered.

Radon-Product Rejection

Annular impactor and tubular filter samples were taken simultaneously in areas where no contamination from airborne Pu was expected. Well ventilated upper-floor rooms and poorly ventilated basement rooms were included to get a range of radon-daughter concentrations. Results are summarized in Table 2.

Samples were counted as soon as possible after being taken, the delay time ranging from 13 to 33 min. They were recounted at a later period and in general showed the decay rate expected for radon-decay products, confirming that the bulk of the activity was due to

TABLE 3—Decay of Sample Taken in Presence of Natural and Long-Lived Alpha Emitters*

Time	*Impactor disk (cpm)*	*Filter tube (cpm)*
0945–0955	Sampling	Sampling
1018–1023	16.6	110
1118–1123	12.4	39
1418–1423	12.2	1.8

* Trial 90. 10-min sample with filter tube following impactor run at 700 l/min.

radon daughters. A slower decay over longer periods of time suggested that thoron daughters may be present in small concentrations.

Trial 90 was carried out in the decontamination center and indicated the presence of small concentrations of airborne long-lived alpha emitters in addition to the natural alpha activity. Results of counting after different delay times are given in Table 3. It is apparent that the impactor-disk count largely represents airborne alpha activity arising from the decontamination work whereas only the natural alpha emitters are sampled by the following filter tube. These figures illustrate very well the power of the annular impactor to discriminate against natural alpha emitters present in the air.

Conclusions

The annular impactor has a high sampling efficiency of about 90% for dusts generated by normal technical processes and a low efficiency of 10% for radon-decay products. It is thus particularly suitable for sampling airborne Pu or long-lived alpha emitters of high toxicity in the presence of a high background of Rn or Th decay products.

Application to sampling beta- or gamma-active particulates, other than daughters of gaseous fission products, requires modification of only the final counting procedure.

Other uses would include sampling large volumes of relatively dust-free air for inactive material. In such a case, the contents of the tray could be subjected to chemical examination. Alternatively, a glass disk could be placed in the tray for subsequent microscopic examination.

* * *

Most of the experimental work in connection with this development was carried out by R. Legere and P. Yourth.

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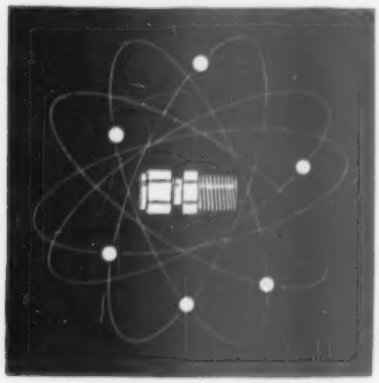

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A System of Megaroentgen Glass Dosimetry

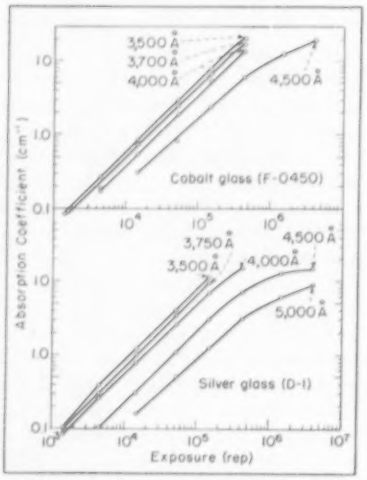
By NORBERT J. KREIDL
and GERALD E. BLAIR
Bausch & Lomb Optical Company
Rochester, New York

The magnitude of the change in visible absorption of most glasses when irradiated by 10^5–10^7 rep of gamma radiation suggests their use in megaroentgen dosimetry. The authors undertook the study of limiting factors at the suggestion of J. F. White (Division of Research, AEC, Washington, D. C.) as a part of the investigation of radiation damage to optical glass (*1*).

The chief limiting factors are sensitivity, linearity, and fading at room temperature. None of the optical glasses investigated have this combination of properties. For example, although the flint glasses color readily with radiation, their rapid fading precludes their use (*2*).

In the investigation of mechanisms that prevent the discoloration of glasses (*1*), it was discovered that transition elements produce prominent and relatively stable absorption in new regions while suppressing, like cerium, the characteristic bands of the parent glasses. For instance, cobalt in a phosphate glass developed a strong near-ultraviolet absorption reaching into the short-wave visible range. It was further learned that the sensitivity increased and fading after exposure decreased with added amounts of cobalt.

Since the less conventional phosphate glass had only been selected because of the ultraviolet transmission required in these researches, cobalt was next investigated in the more conventional silicate glasses. Essentially the same absorption, sensitivity, and stability were found.



ABSORPTION CHANGE with dose of silver and cobalt glasses measured 1 hr after exposure

Although cobalt has been explored to greater detail and more successfully, other transition elements and pairs of transition elements behave similarly.

J. Schulman (*3*) has proposed the use

TABLE 1— Per cent Fading after Storage in Dark at Room Temperature

Glass	Measuring wavelength	Storage time	Fading (%) normalized at 1 hr at various dose levels: 1.5×10^4	5.2×10^4	1.5×10^5	4.3×10^5	1.5×10^6
Cobalt	4,000 Å	1 day	10	7	9	4	
		1 week	19	15	18	21	
	4,500 Å	1 day			5	10	8
		1 week		15	15	19	14
Silver	4,000 Å	1 day	18	18	15	10	
		1 week	29	28	26	25	
	4,500 Å	1 day		23	18	19	17
		1 week		35	27	28	27

of silver-activated phosphate glass for the measurement of high-energy radiation doses. Such radiation produces an absorption band in the near-ultraviolet range of the spectrum and, upon illumination in that band, an orange fluorescence. This fluorescence is most suitable for personnel-dosimetry measurements because of its sensitivity and linearity at low doses (10–10^3 rep) (*4*). Above 10^3 rep, the simpler and direct measurement of absorption is suitable. Sensitivity and linearity appear sufficient up to 10^5 rep, and perhaps, with proper calibration, up to 10^7 rep.

For measuring absorption changes, the Bausch & Lomb Spectronic 20 Colorimeter was investigated in cooperation with C. Klick, Naval Research Laboratory. This instrument is relatively inexpensive and convenient to use. A preliminary study showed that glass and instrument calibrated with a standard high-energy radiation source constitute a system excellently suited for measuring high doses.

Experimental

Glass making. Several melts of the silver-activated phosphate glass (under the designation D-1) having the composition 50% $Al(PO_3)_3$, 25% $Ba(PO_3)_2$, 25% KPO_3, with an addition to this base of 8% $AgPO_3$, were made in an electrical silicon carbide resistance furnace in a clay pot with a capacity of 80 pounds.

Several laboratory melts of soda-lime-silicate glasses having the composition (70% SiO_2, 18% Na_2O, 10% CaO, 1.0% MgO, and 1.0% B_2O_3) containing varying additions of cobalt were made. Glasses containing large additions of cobalt oxide (up to 16% by weight*) showed very high sensitivity to gamma radiation with an absorption change detected at a few hundred reps. However, their high initial optical density makes it difficult to measure, with precision, changes with irradiation.

Preliminary results indicated that satisfactory sensitivity was obtained with 0.5% cobalt oxide addition. This glass was chosen for further experimentation. An 80-pound clay pot melt (experimental melt number F-0450) was made in a gas-fired furnace. Five repeat melts of this glass were made for reproducibility studies.

Adaptor. To obtain accurate read-

* It should be noted that the blue glasses, conventionally used for filters and novelty ware, contain 0.001–0.1% cobalt oxide.

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ings on the glass samples and to obtain reproducible results from instrument to instrument, a special adaptor was developed to hold the dosimeter glasses. The sample size selected as most convenient for reading and exposure was 15×6 mm with thicknesses of 1–3 mm (depending on glass and dose range used). The thickness tolerance was held to ± 0.025 mm for any given thickness.

Calibration. A calibration curve was run on the F-0450 (cobalt) and D-1 (silver) glasses using the Spectronic 20 Colorimeter to read the absorption changes and a kilocurie Co^{60} Source at M.I.T. (*5*) for irradiation.*

The results of this calibration study are represented graphically in the illustration. Each point on the curves represents an average of 4 readings. Readings were taken before and 1 hr after exposure. The plots demonstrate the necessity of measuring at shorter wavelengths for maximum sensitivity and of measuring at longer wavelengths for high doses. The peak of the radiation-induced absorption band in both glasses is in the near-ultraviolet region of the spectrum.

As shown by Fig. 1, the cobalt glass has a change in absorption coefficient of 0.54 after an exposure of 1.5×10^4 rep when measured at 4,000 Å and a change of 0.30 after the same exposure when measured at 4,500 Å. The change is linear with dose from 5×10^3 to 4×10^5 rep when measured at 4,000 Å and from 1.5×10^4 to 4×10^5 rep when measured at 4,500 Å. Above these limits the change with dose is smaller and nonlinear.

Figure 2 shows similar results with the silver glass. This glass has a change in absorption coefficient of 0.76 after an exposure of 1.5×10^4 rep when measured at 4,000 Å and a change of 0.15 after the same exposure when measured at 5,000 Å. The change in absorption coefficient is linear with dose from 5×10^3 to 1.5×10^5 rep when measured at 4,000 Å and from 1.5×10^4 to 4×10^5 rep when measured at 5,000 Å. Above these limits, the change with dose is smaller and nonlinear. However, a measurable change is evident throughout the nonlinear range on the cobalt glass and the silver glass. This smaller and nonlinear change with dose might be explained by saturation effects and by fading during exposure. The same

* The calibrations were carried out with the assistance of S. Goldblith and S. Davison, Food Tech. Dept., M.I.T.

TABLE 2—Mass Absorption Coefficients of Ag and Co Glass

X or γ-ray energy (kev)	Coefficients (cm²/gm) Silver glass	Cobalt glass
65	3.86	0.562
125	0.867	0.406
1,235	0.158	0.143

TABLE 3—Reproducibility of Ag and Co Glass

Conditions		Average deviation from mean Cobalt	Silver
Before irradiation	Between melts	2.0	5.0
	Within melt	2.5	3.0
After irradiation	Between melts	1.0	6.0
	Within melt	0.5	1.5

dose rate and initial reading time after exposure (1 hr) were used for all doses.

Fading. Typical fading data is given in Table 1.* Fading becomes a problem primarily when the dose rate is far different from that used for calibration and when the elapsed time between exposure and reading is of a short duration.

Energy dependence. The radiophotoluminescent response of the silver glass is energy independent above 200 kev, but below 200 kev the response increases, showing a maximum of 18:1 at approximately 65 kev (4). Since the same absorption is directly measured for the high-dose application, the same energy dependence is quite certain to be present.

The energy dependence of the cobalt glass has not yet been measured. However, care was taken to avoid the use of the heavier elements whose specific gamma-ray absorptions in the range 65–200 kev must have affected the energy dependence of the silver glass. Sodium (atomic weight 23), calcium (40), and cobalt (59) were used in the cobalt-silicate glass in place of potassium (39), barium (137), and silver (108) in the silver-phosphate glass.

Using formulas derived by Sun and Sun (6) and data of Brewster (7), we calculated the absorption coefficients or "stopping power" of the silver glass and cobalt glass for three energies. These calculations are summarized in Table 2. The ratios of the absorption coefficients of the silver glass roughly agree with the ratios of the fluorescent response in comparing energy dependence. Although the correlation for the cobalt glass between absorption band and "stopping power" is not known, the energy dependence of the absorption coefficients presumably has an effect on the energy dependence of the absorption band formed with irradiation.

Reproducibility. Reproducibility studies were made on the silver-phosphate glass and the cobalt glass. The results are listed in Table 3.

These differences in reproducibility between the two dosimeter glasses might be explained by the chemical nature of the absorbing centers. The glasses colored with metals, like silver, and some other nonionic chromophores, are generally known for greater sensitivity to melting conditions.

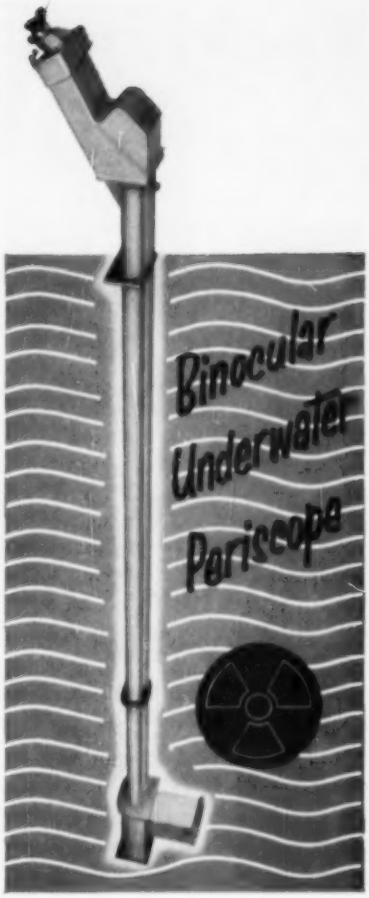
Conclusions

A dosimeter system consisting of a simple spectrophotometer and radiation-sensitive glass is shown by experiment to be suitable for the measurement of routine doses of high-energy radiation in the dose range of 5×10^3–4×10^6 rep. It could be extended to dose rates and radiation energies widely different from those reported by recalibrating under conditions of use. It has the advantages over other methods of ruggedness, low cost, and good reproducibility.

Silver-phosphate glass has been shown in detailed tests (3), including exposures to varying energies, dose rates, and doses, to be suitable as a sensitive element in this system. A cobalt glass (F-0450) in more limited tests covers the same dose range with approximately half the fading when measured at the longer wavelengths necessitated by high doses.

The control of radiation response of cobalt glass is easier than that of silver glass because of the chemical insensitivity of cobalt in glass melts to temperature and oxidation-reduction conditions. These factors should favorably

* A note will be published in the February "Cross Sections" department describing new cobalt glasses having more stable absorption bands.



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affect manufacturing costs and permit consideration of the expendable use of dosimeter glass.

* * *

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BIBLIOGRAPHY

1. N. J. Kreidl, J. R. Hensler, NYO-3780 (1954); to be published in *J. Am. Ceram. Soc.*
2. G. S. Monk. The coloration of optical materials by high energy irradiations, ANL-4536 (1950)
3. J. H. Schulman, C. C. Klick, H. Rabin, NUCLEONICS **13,** No. 2, 30 (1955)
4. J. H. Schulman, W. Shurcliff, R. J. Ginther, F. H. Attix, NUCLEONICS **11,** No. 10, 52 (1953)
5. S. Davison, S. A. Goldblith, B. E. Proctor, M. Karel, B. Kan, C. J. Bates, NUCLEONICS **11,** No. 7, 22 (1953)
6. L. L. Sun, K. H. Sun, *Glass Ind.* **29** (12) 686–91, 714, 716 (1948)
7. G. F. Brewster, *J. Am. Ceram. Soc.* **35,** No. 8 (1952)

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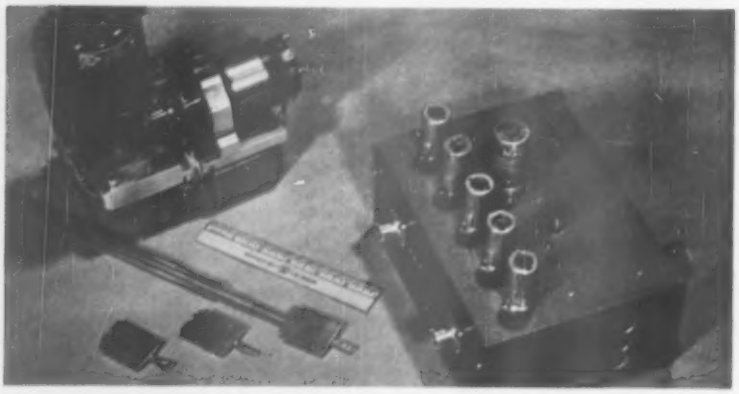

FIG. 1. Fission chambers, amplifier, probe, and drive unit. Fission-chamber movement within assembly is controlled by probe and drive unit. D-C motor drives probe through rack and pinion gear. Chamber position is determined by Selsyn indicator attached to drive pinion and connected electrically to duplicate unit on remote-control panel

Fission Chamber Measures Neutron Distribution Quickly, Accurately

By ROBERT G. NOBLES and ALAN B. SMITH
Argonne National Laboratory, Lemont, Illinois

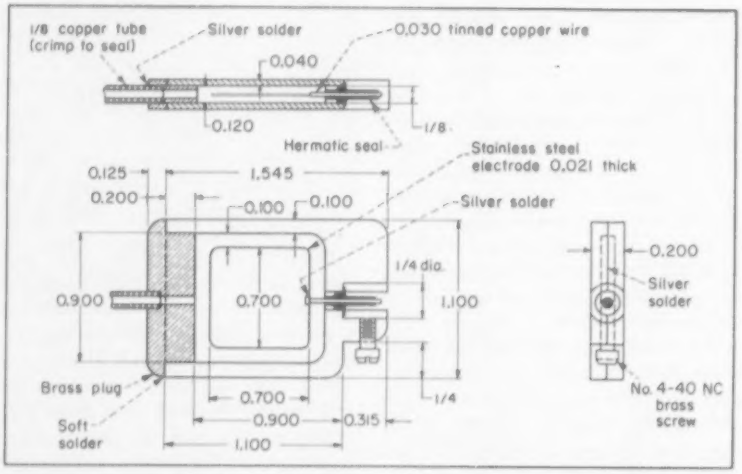

FIG. 2. Construction of fission chamber. Shell is two 0.1-in.-thick pieces of mild steel hard-soldered together. Set screw attaches chamber to probe; hermetic seal (Hermetic Seal Co., Newark, N. J.) is soft-soldered in screw recess. Electrode combines 1-in² area with minimum of electrical capacitance; 100-μg/cm² coating of fissionable material is applied to electrode. Coating method (1): nitrate of fissionable material, dissolved in Zapon lacquer binder, is painted on electrode; electrode is heated to 500° C, burning off lacquer and converting coating to oxide. Finished surface is smooth and tenacious; satisfactory coatings of neptunium, uranium, and plutonium are easily obtainable

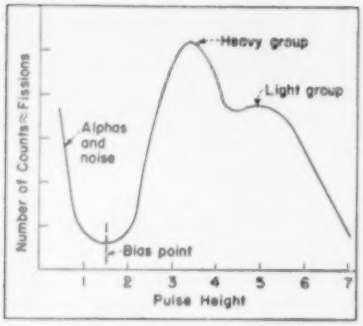

FIG. 3. Differential analysis of pulses from fissions in U^{235} chamber in thermal flux of 10^5 n/cm²/sec. Fissionable coat is not "thin." "Double-humped" distribution is characteristic of U^{235} thermal fission (2). Minimum between alpha-particle and fission-fragment pulses is usually chosen as bias point for electronic discriminators

A fission chamber for flux studies within a multiplying assembly must satisfy several conditions:

1. Design is governed by the space available.

2. The material and the size must not unduly perturb the neutron flux.

3. The detector must be sensitive enough to make reliable measurements at the available flux levels.

4. To determine energy distribution, facility in interchanging chambers containing different fissionable materials is important.

Figures 1 and 2 show a chamber and probe unit that satisfy these criteria.

The chamber is connected to a preamplifier that contains a 300-volt-battery high-voltage supply. This compact unit can be placed in very confined regions. The preamplifier output is fed to a linear amplifier (model 203, Atomic Instrument Co., Cambridge, Mass.) and then to an integral discriminator. Chamber events producing voltage pulses above the discriminator setting are recorded on a "scale

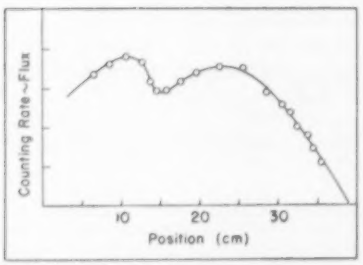

FIG. 4. Typical flux distribution

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602	30 to 400	100-300-1000	10 to 9990	x-ray therapy
603	400 to 1300	5000-15,000-50,000	500 to 499,500	On telecurie gamma sources
604	10 to 30	100-300-1000	10 to 9990	Low energy therapy
605	400 to 1300	1-3-10	0.1 to 99.9	Gamma ray sources
606	400 to 1300	10-30-100	1 to 999	Gamma ray sources
607	400 to 1300	100-300-1000	10 to 9990	Gamma ray sources
608	30 to 400	1-3-10-r/hr.	1 to 999 / 600	Survey in vicinity of x-ray machines.
612	6 to 35	100-300-1000	10 to 9990	Low energy therapy
613	30 to 400	0.1 - 0.3 - 1	0.01 to 9.9	Survey in vicinity of x-ray machines.

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of 1,000." A differential pulse-height analyzer is included as an aid in studying counter performance.

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The chamber is filled with four atmospheres of spectroscopically pure argon. This pressure is sufficient to cause the heavily ionizing fission fragments to expend a large amount of their energy in the chamber gas. Most of the longer-range alpha particles from the natural activity of the fissionable material will expend the larger part of their energy in the chamber walls. Thus a proper adjustment of the gas pressure for the given geometry materially helps to decrease the pulse pile-up from high-alpha-active materials such as plutonium.

Figure 3 shows the differential pulse-height analysis for a U^{235} chamber.

The chambers described are capable of a rapidity and accuracy of flux measurement exceeding that associated with the usual foil techniques. Throughout a set of measurements, a close examination and control of the experiment is possible. The effective neutron sensitivity of the chamber greatly exceeds that of a similar fissionable foil irradiated for a reasonable length of time. This is of particular value when one is studying the response of threshold detectors such as U^{238}. Good measurements are obtainable at flux levels too low to permit reliable activation measurements.

Since one measures only the actual fission rate, the build-up of product activity is not a problem. The detectors may be used as often as desired and thus accomplish a considerable saving of scarce fissionable material, such as Np^{237}. An example of the type of experimental distribution that can be obtained is shown in Fig. 4. Notice the detail and precision of the measurement.

BIBLIOGRAPHY

1. B. Rossi, H. Staub, "Ionization Chambers and Counters" (McGraw-Hill Book Co., Inc., New York, 1949)
2. Brunton *et al.*, *Can. J. Research*, Sec. A, **28** (1950)

Preparation of C^{14} Standard for Liquid Scintillation Counter

By D. L. WILLIAMS, F. N. HAYES, R. J. KANDEL, and W. H. ROGERS
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Counting C^{14} by liquid-scintillation methods prompted the search for an easily prepared, accurate activity standard. Such a standard should be soluble in toluene and relatively nonvolatile.

Carbon dioxide is an ideal starting material because it can be obtained in high specific activity from Oak Ridge barium carbonate and because the atom per cent C^{14} can be determined with great accuracy in a mass spectrometer.

Benzoic acid was an obvious choice as the standard since, in addition to being a toluene-soluble solid, it can be synthesized in high yield from carbon dioxide with no difficulties in the isolation and purification steps.

Standardization of $C^{14}O_2$

The carbon-C^{14} dioxide samples for mass-spectrometric analysis were prepared using vacuum apparatus. Barium carbonate (10% C^{14}) was mixed with an equal weight of ordinary barium carbonate in a generator flask. Concentrated sulfuric acid, degassed by heating, was added to a compensated funnel and, with a trap immersed in dry ice, the apparatus was evacuated.

The sulfuric acid reservoir was warmed with a small flame until no more bubbles appeared in the acid. With the apparatus isolated from the vacuum line, the carbon-C^{14} dioxide was generated and condensed in a small mixing bulb (of approximately 5-ml capacity) with liquid nitrogen. Finally, the acid mixture was stirred with a glass-enclosed magnet and warmed until gas evolution ceased. After about one-half hour, the apparatus was again briefly evacuated to remove noncondensable gases. The carbon-C^{14} dioxide was allowed to vaporize and enter a shipping flask* and 3 storage flasks.

To insure homogeneity of the sample before its division, the carbon dioxide was transferred into one of the flasks and back into the mixing bulb five

TABLE 1—Standardization of Carbon-C^{14} Dioxide

Sample no.	*Instrument*	*Atom per cent C^{14} isotope*	*Number of assays*
1	Consolidated Model 21-103	5.97 ± 0.04	20
2	Consolidated Model 21-103	5.92 ± 0.02	24
3	Consolidated-Nier Model 201	5.88 ± 0.06	3

TABLE 2—Comparative Counting of Benzenecarboxylic-C^{14} Acid Samples

Solution number	*Counting data* (cpm)*	*Averaged data (cpm)*	*mg counted*	*cpm/mg*
1	63,220 ± 252			
		63,257 ± 200	1.513×10^{-2}	4.181×10^{7}
1	63,294 ± 128			
2	69,684 ± 200			
		69,657 ± 220	1.671×10^{-2}	4.169×10^{7}
2	69,630 ± 237			
3	61,180 ± 327			
		61,408 ± 286	1.472×10^{-2}	4.172×10^{7}
3	61,635 ± 238			

* Averaged from four 1-min counts on each sample.

times. One sample was retained for synthesis of the benzenecarboxylic-C^{14} acid (benzoic acid) standard; the other three samples were analyzed mass spectrometrically by three separate spectrographic laboratories: the Mass Spectrometry Section of the Atomic and Radiation Physics Division of the National Bureau of Standards and two installations at the Los Alamos Scientific Laboratory. The results are given in Table 1.

Labeled-Acid Preparation

The preparation, carbonation and hydrolysis of the Grignard reagent was completed under an atmosphere of dry nitrogen in closed apparatus. This eliminated transfer of the reagent and possible dilution of the isotope by atmospheric carbon dioxide.

After the oven-dried apparatus was assembled, evacuated to 2 microns overnight, and tested for leaks, 0.243 gm (10 millimoles) of magnesium was placed in a reaction flask, which contained a glass-enclosed magnetic stirrer. While flushed with dry nitrogen, the flask was warmed with a small flame and allowed to cool. Then, with nitrogen flowing through the side tube, a solution of 1.57 gm (10 millimoles) of bromobenzene in 30 ml of dry ether was run into a compensated addition buret. The reaction was started with 5 ml of this solution, the remainder was added dropwise during one hour, with stirring, and the solution was stirred for an additional hour. The solution of phenylmagnesium bromide was then frozen in liquid nitrogen and the apparatus was evacuated. The reagent was melted with a dry ice-acetone bath at $-80°$ C, again frozen with liquid nitrogen, and the apparatus was re-evacuated and tested for leaks.

The sample of $C^{14}O_2$ (estimated to be 1.56 millimoles) was frozen with liquid nitrogen. Connecting tubing and flask were evacuated and the $C^{14}O_2$ was distilled into the reaction vessel, which was again isolated.* The phenylmagnesium bromide solution was thawed in a bath at $-80°$. Then with the reaction flask immersed in a bath at $-20°$, the mixture was stirred for 10 min. Following this period, the solution was twice alternately cooled to $-80°$ and stirred at $-20°$ to insure complete reaction of the $C^{14}O_2$. The

* This flask was prepared with a pressure stopcock and standard tapered joint at each end and a break-seal. After the flask was filled, the bulb was cooled in liquid nitrogen and the inlet tube was sealed off.

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reaction vessel was filled with dry nitrogen and, while a flow of nitrogen was maintained through the side arm of the addition buret, 5 ml of freshly boiled 6*N* hydrochloric acid was introduced into the buret. With the stopcock leading to a calcium chloride-Ascarite tube open, a slight flow of nitrogen through the apparatus and rapid stirring of the solution, the hydrolysis acid was added. The mixture was then warmed with a water bath so that refluxing ether washed the walls of the reaction vessel and complete hydrolysis of unused Grignard reagent was assured.

After the addition of 10 ml of 6*N* potassium hydroxide solution, the mixture was stirred for 20 min and transferred to a liquid-liquid extractor with water. The basic solution was extracted with ether for 22 hr to remove by-products. The aqueous phase was then acidified with 6*N* hydrochloric acid and the benzenecarboxylic-C^{14} acid was extracted with ether for 15 hr. The ether solution of product was transferred to a vacuum sublimator and carefully evaporated to dryness. The product was then sublimed for 15 min at 0.2 mm pressure and a bath temperature of 77° C. The product, 192 mg (1.57 millimoles), was washed from the sublimator with ether, evaporated to dryness and recrystallized from 5 ml of *n*-hexane, cooled to 6° overnight and then −10° for 45 min. The colorless product, dried under vacuum, weighed 186.8 mg (97.5% return) and melted at 122° C.

As checks on the reproducibility of the standard and the reliability of the standardization procedure, benzenecarboxylic-C^{14} acid was prepared from the unused portion of two of the samples of $C^{14}O_2$ subsequent to mass spectrometric analysis. The preparations were carried out according to the procedure described previously.

Comparison of Standards

Solutions were prepared for scintillation counting by dissolving approximately 1-mg quantities (weighed on a microbalance) of each of the three samples of benzoic acid in one liter of toluene. To each solution was added 100 mg of nonradioactive benzoic acid so that adsorption of benzenecarboxylic-C^{14} acid on glass would be insignificant. Previous studies (*1*) with benzoic acid had shown that concentrations less than 2 mg/l introduced serious adsorption problems.

Solutions for counting were prepared by adding 1 ml of one of the benzoic acid solutions to 85 ml of toluene containing 4 gm/l of 2,5-diphenyloxazole (PPO) and 0.05 gm/l of 1,4-di-[2-(5-phenyloxazolyl)]-benzene (POPOP). The solutions were counted at about 60% efficiency with a Los Alamos Model 530 coincidence system (*2*) operating with photomultipliers at room temperature.

Duplicate aliquots from each benzoic acid solution were counted to better than 0.5% statistics. The counting data (Table 2) allowed calculation of three average values of cpm/mg, one for each benzenecarboxylic-C^{14} acid sample. The agreement was such that the greatest deviation from their average was only 0.2%.

The data show conclusively that the three benzoic acid standards had the same specific activity.

TABLE 3—Assay of Carbon-C^{14} Dioxide

$C^{14}O_2$ *sample*	*Atom per cent* C^{14} *isotope*
Original	5.96 ± 0.01
From benzoic acid No. 1	6.00 ± 0.02
From benzoic acid No. 2	6.00 ± 0.02

Isotopic Fractionation

In a preliminary study, a $C^{14}O_2$ sample was prepared, divided into two approximately equal portions and assayed mass spectrometrically.

Benzenecarboxylic-C^{14} acid was then prepared from each of the samples of carbon dioxide, according to the procedure already described. A part of each benzoic acid preparation was oxidized to carbon dioxide and water in a microcombustion apparatus. Each sample of this carbon dioxide, freed of oxygen and water vapor, was also assayed mass spectrometrically.

The results, shown in Table 3, indicate that neither isotopic dilution nor isotopic fractionation occurred during preparation of the standard acid. The C^{14} values for the two samples of $C^{14}O_2$ derived from benzoic acid are corrected for the dilution due to the C^{14} isotope introduced via the benzene nucleus.

* * *

This work was done under the auspices of the U. S. Atomic Energy Commission.

BIBLIOGRAPHY

1. F. Newton Hayes. Liquid Solution Scintillators. LA-1639, p. 70 (1954)
2. R. D. Hiebert, R. J. Watts. Nucleonics **11**, No. 12, 38 (1953)

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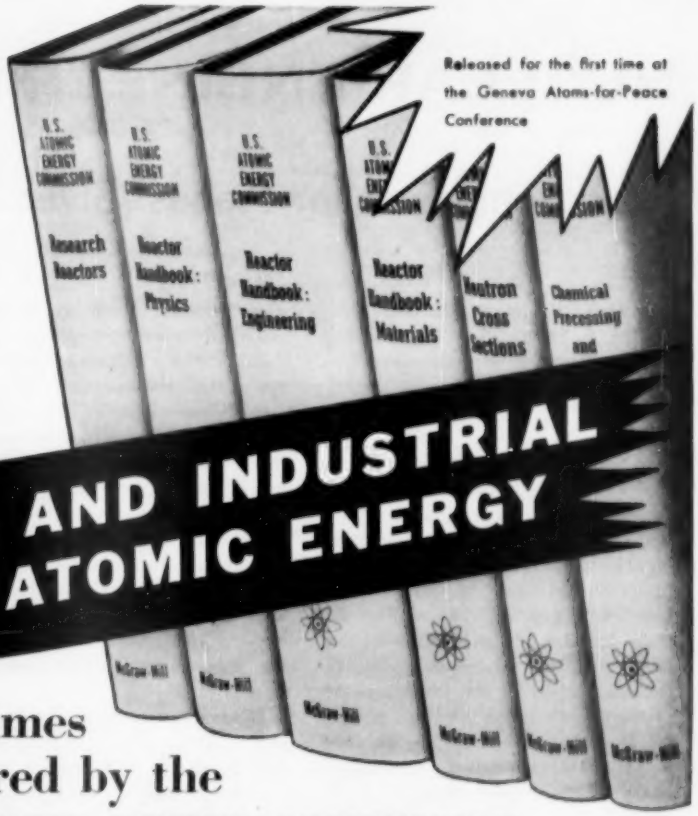

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NUCLEAR ENGINEERING

Irradiating Smaller Pieces Gives Stronger Co^{60} Sources

By LAWRENCE H. LANZL and LESTER S. SKAGGS
Argonne Cancer Research Hospital
The University of Chicago
Chicago, Illinois

Where limitations on dimensions of Co^{60} sources are important for the particular application, irradiation of several small samples in the reactor gives higher radioactivities than irradiation of a single large specimen. Large specimens depress the reactor flux more because of the net flow of neutrons into the absorber. Also, the central portion of the large absorber is exposed to fewer neutrons because of the high peripheral absorption. These effects are called "flux depression" (*1*) and "self-protection" (*1, 2*), respectively.

The moving-beam radiation-therapy unit at Argonne Cancer Research Hospital has a geometry that limits the source diameter to 0.75 cm. Thus, the 11.7-gm source planned would be 0.75 cm in diameter, 3 cm long, with total activity of 1,800 curies (specific activity = 154 c/gm).

Single-piece samples. Absolute measurements made at Brookhaven National Laboratory (*1*) on a piece of cobalt of these dimensions showed that the sample reached only 45% of the activity calculated on the basis of no flux depression or self-protection. Self-protection gave a factor of 0.77 and flux depression gave 0.58.

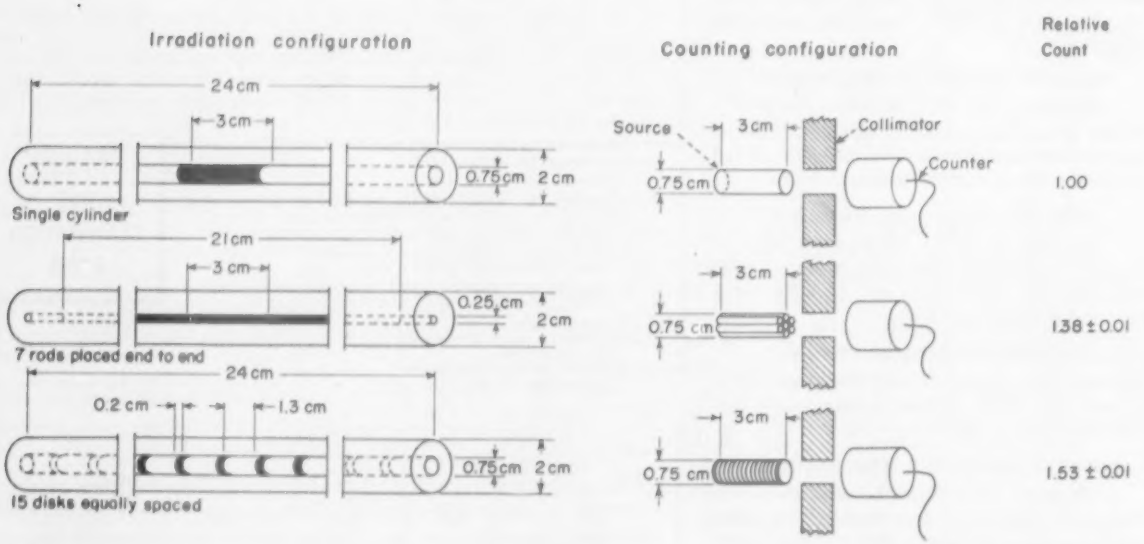
Actual experience in the production of a 658-curie Co^{60} source of the same size in the Materials Testing Reactor showed that the activity reached only 36% of that calculated for an infinitesimal-size specimen (that is, one having no "flux depression" or "self-protection").

Effect of irradiating divided specimens. Both self-protection and flux depression can be decreased by dividing the source into a number of smaller pieces and dispersing the pieces throughout a greater volume of the reactor during activation. To compare the value of various configurations, a flat-flux region of the CP-5 reactor at Argonne National Laboratory was used to irradiate the three assemblies shown in the figure. Each assembly, which consisted of graphite cylinders with the samples mounted inside, was irradiated for two minutes in a flux of approximately 7.5×10^{11} n/cm²/sec.

For convenience, the samples were allowed to decay for several days before measurement; this also served to eliminate the 10.4-min isomeric activity. The sources were made from very high purity cobalt, and no other activity was found. The combined effect of flux depression and self protection was evaluated by counting the gamma activity of the sources with an end-window G-M tube.

For measurement, the disks were stacked one above the other to form a volume equivalent in size and shape to that of the single piece. The rods were arranged with one in the center and the other six stacked around the first. This formed a bundle with over-all dimensions equal to the single piece, but, because of the interstitial air spaces, the weight was only 78% of either the single piece or the disks.

The radiation was measured along the axis of the cylindrical assembly in each of the three cases and was collimated so that only the radiation from the end of the source, i.e., from a cir-



cular area of 0.75-cm diameter, was detected. An aluminum filter, sufficiently thick to stop all beta particles, was placed between the source and the counter.

The activities, normalized to unity for the single piece, were as shown in the figure. These results appear to favor dividing the single large source into a number of disks; but if account is taken of the 22% reduction in weight with the rods, and if the calculations are made on the basis of specific activity, then the result for the rods is 1.77. Thus, if the rods were made so that there were no interstitial air spaces when stacked together, the activity would be approximately 1.77 times that for the single source.

If the Brookhaven result for self-absorption and flux depression of 45% for the single large cylinder is used, we see that dividing the source into seven cylindrical rods would make the figure 62%; and for dividing the source into 15 disks, it would be 69%. And again, if we had used close-packed rods and neglected any difference in gamma absorption, the flux depression and self-absorption would only reduce the activity to 80% of the ideal.

* * *

The authors would like to thank J. E. Rose and W. H. McCorkle, Argonne National Laboratory, M. A. Klose, Argonne Cancer Research Hospital, and W. B. Lewis, Materials Testing Reactor, for their assistance in this work.

BIBLIOGRAPHY

1. J. S. Levin, D. J. Hughes, NUCLEONICS **11**, No. 7, 8 (1953)
2. D. T. Green, R. F. Errington, F. C. Boyd, N. J. Hopkins, NUCLEONICS **11**, No. 5, 29 (1953)

Calibrating Power Level of a Water-Boiler Reactor

By J. W. FLORA* and J. W. SHORTALL†
California Research and Development Company, Livermore, California

Three essentially independent sets of data were used to calibrate the power-level instrumentation of the 500-watt water-boiler reactor at the Livermore Research Laboratory of the U. S. Atomic Energy Commission (*1*). Sources of the data were: (a) gold-foil induced activity resulting from exposure in the core; (b) fission-product activity from core irradiation of enriched uranium oxide, and (c) heat transfer to the reactor coolant. Calibration resulting from these data appears accurate to ±10% for 95% confidence limits. The maximum thermal-neutron flux is 2.6×10^{10} n/cm²/sec at a power level of 500 watts.

Gold-foil irradiations. Commercially supplied gold foil, 0.0025-in. thick by ½-in. o.d., were used to make the power standardization. The foils were mounted on 1-in.-o.d. by 1/16-in.-thick Lucite backing discs. A number of foils were prepared, mounted, and intercalibrated in a known, precisely reproducible geometry to obtain foil factors, which normalize the foil activities and correct for small deviations in purity, density, thickness, and mounting imperfections.

Four of the gold foils were sent to Oak Ridge National Laboratory where they were irradiated in the Oak Ridge standard pile in a known flux and cadmium ratio. When returned, they were counted in seven pig-scaler combinations several times, and corrected saturated activities were computed. It was then possible to relate the thermal-neutron-induced activity of each foil to the thermal-neutron flux incident upon it during its exposure. This relation was determined to be 3.60 ± 0.07 n/cm²/sec per cpm saturated activity, under the most favorable counting geometry possible with standard end-window tubes. The corresponding value for indium foils of the same diameter and 0.005-in. thickness is 1.8.

To determine reactor power it is also necessary to know the neutron distribution in the core. To obtain this curve several foils were exposed on a radius of the core. Three types of foils—gold, uranium and indium—were used. The resulting curve is shown in the figure. The fitted curve has a value of 0.31 in.$^{-1}$ for k in

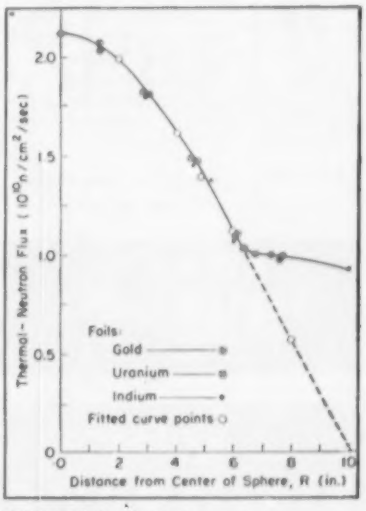
$$\phi = \phi_0(\sin kr/kr)$$

The ratio of average to peak fluxes was determined as 0.671 from integration of this expression over the volume of the core.

The flux corresponding to 1 watt of boiler power is now taken as

$$\phi_{1A} = 3.3 \times 10^{10} A/0.671 M A_0 \sigma_f 1.07 = 4.75 \times 10^7 \text{ nv/watt}$$

where: A = atomic weight of U^{235}; σ_f = fission cross section of U^{235} = 549 barns; M = mass of U^{235} in the core = 687.3 gm; A_0 = Avogadro's number; 0.671 = ratio of average to peak fluxes; 1.07 = number of fissions occurring above the cadmium cutoff, as derived from ref. (*2*); 3.3×10^{10} = number of fissions/sec/watt, assuming 190 Mev/fission is released in the core (*3*).



NEUTRON distribution in core

To determine power from a foil measurement, its corrected saturated activity is multiplied by

$$P = \frac{3.60 \text{ nv/cpm}}{4.75 \times 10^7 \text{ nv/watt}} = 7.6 \times 10^{-8} A_s$$

where A_s is the saturated thermal activity. Precision of results was calculated to be ±3% for 95% confidence limits; over-all accuracy is estimated and calculated to be ±10%, not including errors of calibration of the ORNL standard pile (*4*).

Fission-product analysis. Several samples of uranium oxide, procured

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from leftover fuel solution, were sealed in thin aluminum foil. These foils were then scotch-taped to Lucite disks. About 1 mg of uranium was contained in each foil. The foils were irradiated in the core center to about 10^{12} nvt. Using standard radiochemistry carrier technique for Zr^{97} and Ba^{139}, separations were effected and these activities determined by use of chlorine-filled counters standardized to a 4π counter.

Using Zr^{97} as an example, the procedure used was as follows. After irradiation, the foils were dissolved individually in HCl and a small quantity of HNO_3, and a known amount of Zr (about 10 mg) was added as carrier. The HNO_3 was boiled off. The solution then was made up to 10 ml of $4N$HCl. The Zr then was extracted by adding an equal volume of thenoyltrifluoroacetone (TTA) in benzene. The TTA was washed once with an equal volume of $4N$HCl and twice with equal volumes of $8N HNO_3$; the water phase was discarded each time. The residual was then boiled down, ignited, weighed, and counted. Other chemical procedures applicable to this problem have been published (*5*).

If C_0 is the actual counting rate of the sample extrapolated back to the end of the irradiation period and A_0 is the number of Zr^{97} atoms present at that time, the two values are related as: (C_0/λ)(chemical yield)(counting geometry 4π correction)(self-absorption correction)(daughter correction) $= A_0$. The daughter correction is due to the necessity of subtracting out the niobium-97 activity, and is the only factor not determined experimentally. Substituting typical values for a 15-min irradiation

$$A_0 = (3.6 \times 10^4/6.8 \times 10^{-4})(2.91)(31.6)(0.714)(0.485) = 1.69 \times 10^9 \text{ atoms } Zr^{97}$$

If N is the number of U^{235} atoms in the original sample, σ_{eff} the production cross section for Zr^{97} (the product of the fission cross section and the fission yield of Zr^{97}), t the time of sample exposure, and ϕ the thermal neutron flux

$$\phi = A_0/N\sigma_{eff}t$$

For the exposure mentioned

$$\phi = 1.69 \times 10^9/(2.16 \times 10^{18})(549 \times 10^{-24})(0.062)(900) = 2.56 \times 10^{10} \text{ n/cm}^2\text{/sec}$$

Calorimetric method. The most straightforward means of calibrating this type of reactor is by heat-transfer measurement. However, it is necessary that the core be allowed to dissipate several hundred watts of power so that the results will be accurate.

With the core operating at ~500 watts, a steady flow of coolant was circulated in an amount necessary to maintain the core temperature in equilibrium with the surrounding reflector. In the inlet and outlet lines, at locations within 3 ft of the core, thermistors and thermocouples were placed. Temperature differences of approximately 8° F were measured with a flow rate of about 0.45 gpm.

This method of power calibration is ideally suited for periodic checking of instrumentation since it can be accomplished with a minimum of effort and does not require the use of an experimental facility or restrictive power level.

Power calibration of research reactors also may be attained by other techniques (*6, 7*).

* * *

The authors thank W. K. Burns, R. S. Gilbert, and F. C. Dietz for assistance in foil measurements and T. I. Arnette of ORNL for standard pile exposures.

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BIBLIOGRAPHY

1. J. W. Shortall, J. W. Flora, R. H. Graham, A. V. Shelton, LRL-136 (1954)
2. E. B. Johnson, J. L. Meem, ORNL-1438 (1953)
3. J. L. Meem, Nucleonics **12**, No. 5, 62 (1954)
4. E. D. Klema, ORNL-1398 (1952)
5. M. Lindner, UCRL-4377 (1954)
6. L. D. P. King, R. E. Schreiber, AECD-3054 (1944)
7. J. L. Meem, *et al.*, ORNL-1537 (1954)

Carbon Steel Promises Cheaper Reactor Systems

By R. U. BLASER and J. J. OWENS
Research Center
The Babcock & Wilcox Co.
Alliance, Ohio

Economic studies of nuclear power plants usually show that some of the more important cost items include: (a) fuel-element fabrication, chemical reprocessing, and subsequent refabrication; (b) maintenance, and unusual requirements associated with radioac-

tive systems; (c) relatively high capital investment.

High capital costs often result from the additional complexity of a nuclear system, but in many cases they are further increased by the commendable desire to be on the safe side by a large margin. Such safety factors are large as the result of the many uncertainties, technical and otherwise, and therein lies the need for a large amount of research and development work to reduce costs.

For example, to avoid corrosion problems, the best and usually the most expensive materials have been used for each application. Quite often this also increases fabrication costs and delivery times. However, it has not been demonstrated that more common, lower priced materials such as carbon steel are unsatisfactory.

In power plants for water-cooled reactors, as in other new processes, stainless steel has been used for its obvious advantages in regard to corrosion resistance. However, the items of cost, availability, construction time, and difficulties in fabrication are in almost all cases in favor of carbon steel as a construction material. Thus, if it can be shown that the corrosion resistance of carbon steel in relatively pure water is satisfactory or can be made acceptable by proper water treating, we would advance another step toward more economical equipment and cheaper atomic power.

Information Available

Such an investigation of the corrosion of carbon steel in water has been performed at Babcock and Wilcox Company.* In this experimental program, about 1,000 specimens were used in 70 tests in which 14 water conditions were investigated. Test times were as short as one hour and some have been as long as 5,000 hours in a 16-month program. All corrosion was reported on a descaled basis to avoid errors from corrosion products remaining on the specimens.

Time as a Variable

The variable of greatest importance was time. The corrosion rates of carbon steel and low alloys were relatively high initially. But, as the clean surfaces build up a semiprotective layer of oxide, the total corrosion tapers off

* R. U. Blaser, J. J. Owens. Special corrosion studies of carbon and low-alloy steels (American Society for Testing Materials Symposium on High-Purity-Water Corrosion, June 28, 1955).

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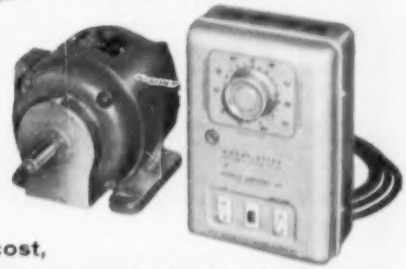

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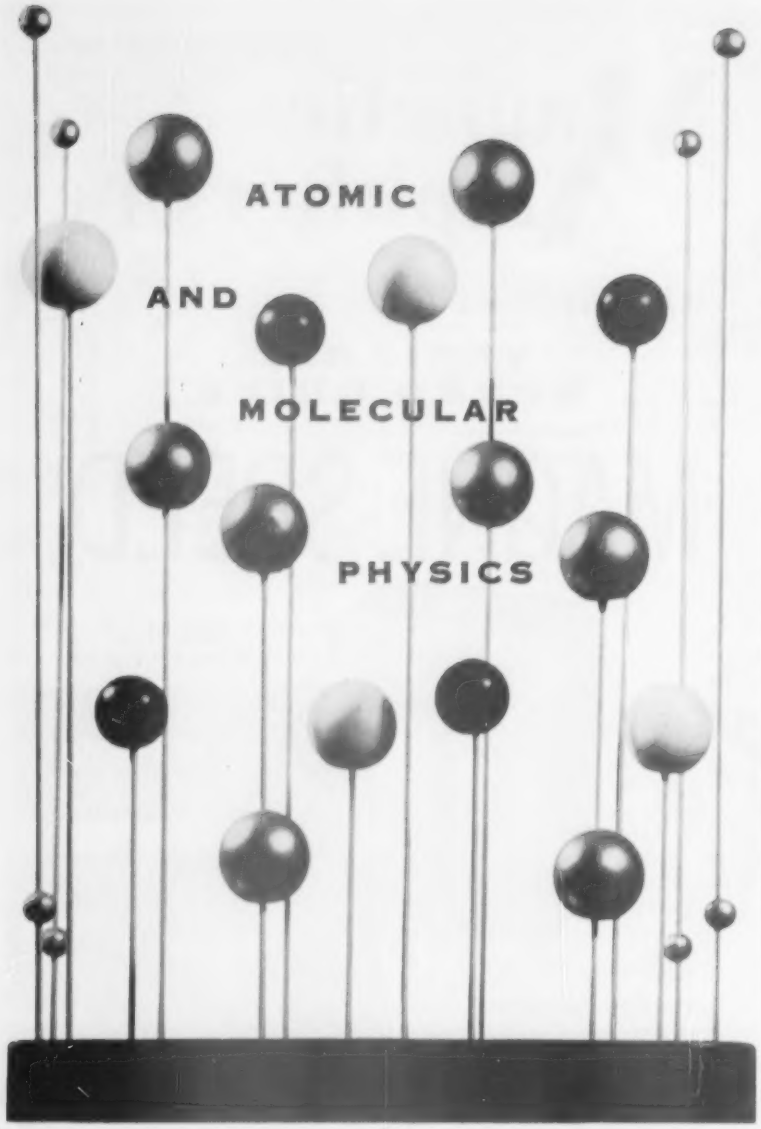

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Molecular structure model, courtesy California Institute of Technology

The Hughes program will be concerned with investigation of atomic frequency and time control devices of unprecedented accuracy, and with atomic amplifiers of unprecedented low noise.

SCIENTIFIC STAFF RELATIONS

HUGHES

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AND DEVELOPMENT

LABORATORIES

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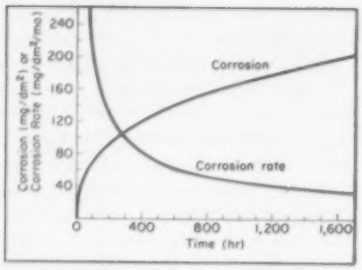
Los Angeles County, California



CORROSION of A212 carbon steel in 600° F water flowing at 30 ft/sec

and the instantaneous rate rapidly decreases. Representative curves showing this action are shown in the figure.

Surface Finish

Previous work with stainless steels had shown that corrosion rate was a function of surface finish. But surface finish had no detectable effect on A212 and other carbon steels tested. Electropolishing did decrease the corrosion rate of the low chromium alloys, such as A-335-P11 and A-335-P22. It is believed that any effect of surface finish on the corrosion of carbon steels may be masked by the high initial corrosion rate.

Effect of Velocity

The majority of the tests were run at velocities of 30 ft/sec and 1 ft/min. The corrosion rate after descaling is higher for the 30 ft/sec velocity condition than for the 1 ft/min velocity. Also, the low-velocity specimens retain a higher percentage of the corrosion products than the high-velocity specimens. Therefore, without the use of descaling methods, the low velocity specimens appear to have corroded far less. Descaling of such specimens must be used to obtain quantitative data that can be correctly interpreted. No increase in corrosion was observed when the velocity was increased from 30 to 40 ft/sec.

Effect of Temperature

Temperatures of from 200° F to 750° F have been investigated during this work. Little, if any, increased corrosion can be attributed to temperatures between 500° F and 680° F. But, a limited number of tests at 750° F and 3,500 psi on carbon steel indicated that corrosion under these "above-critical" water conditions can be five times that at 680° F under some conditions. More work is being done at this higher temperature to verify the results obtained.

Conclusions

The results indicated that corrosion is highest for a clean specimen at the start of a test and that the corrosion rate decreases rapidly with time of exposure. After 6 months, indicated corrosion rates at 600° F are below 20 mg/dm²/mo. or about 0.0001 in./yr. The specimens in semistatic water retain more scale and have a lower rate of total corrosion and loss of iron to the water than the specimens at high velocity.

The data indicate an advantage of water treatment. The various additives show little difference in corrosion results at 600° F as long as *p*H of about 10 or more is used. Nuclear considerations may be more important in the choice of water treatment for reactor applications.

Heat-transfer tests, metallographic examinations, and other observations did not reveal any insurmountable problems in the use of carbon steel in high-purity water.

Much work remains to be done on the corrosion of carbon steel in high-temperature pure water and the amount and effect of carbon-steel corrosion products in reactor systems. However, it is believed that sufficient information is available to permit design of a carbon-steel reactor system at this time. Current and future work is aimed at putting such designs into practice.

REACTOR FACTS

Estimate of economic minimum for fuel reprocessing. About 1,000,000 electrical kw of nuclear capacity is needed to support an economical chemical reprocessing plant for reactor fuel elements.

A "generation" in power reactor development runs 5–7 years. Even with normal telescoping and overlapping, about 5–7 years is required to complete a new reactor based on technology demonstrated in operating the previous one. This was the estimate made recently for the Iowa Utilities Association by AEC's W. Kenneth Davis. Once a project starts, scheduling proceeds something like this: component development and testing, 1–3 yr; engineering design, 1 yr; construction, 2–3 yr; testing and initial operation, ½–1 yr; significant operation, 1–3 yr.

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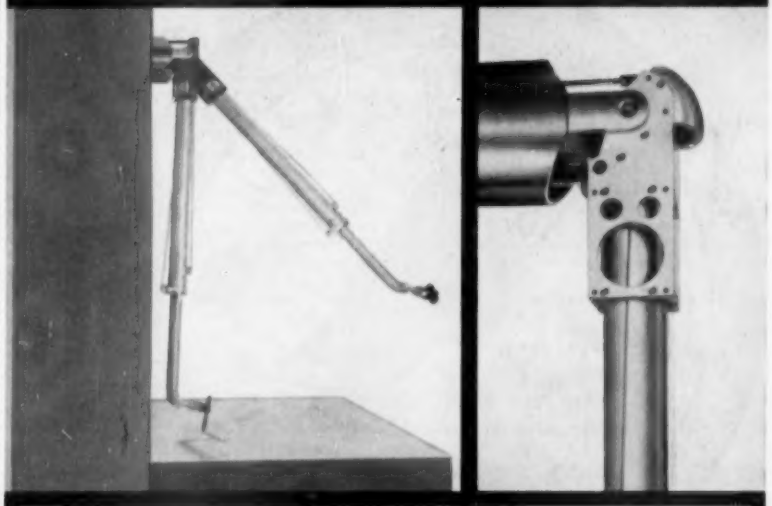

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Contact J. M. Hollyday, Dept. N-1, The Martin Company, Baltimore 3, Maryland.

MARTIN
BALTIMORE

NEWSMAKERS

Dr. Edward Chester Creutz has been appointed director of research of the General Atomic Division of General Dynamics Corp. and of the division's pure and applied science laboratory, G-D announced. Creutz has been professor and head of the physics department and director of the Nuclear Research Center at Carnegie Tech since 1949, and currently has been working on a special assignment with Project Sherwood—the AEC's controlled fusion program.

A. P. Fontaine has been named vice-president for engineering and a member of the administration committee of Bendix Aviation.

Charles M. Dick Jr. joined Metal & Thermit Corp. to direct its staff of sales engineers handling Kel-Ray projectors for industrial radiography with gamma rays from radioisotopes.

Dr. F. W. Albaugh was picked by General Electric as manager of its advanced engineering section at Hanford. Former senior technical specialist at HAPO, he replaces **W. Kelly Woods** who has been assigned to head GE's technical activities on the Commonwealth Edison dual-cycle boiling reactor project.

Atomic Development Securities Co. Inc. announces appointment of **John E. Lotspiech** as a vice-president of the company, which is distributor for the Atomic Development Mutual Fund Inc. He will continue his present assignment as West Coast representative.

Brush Electronics Co. named **John H. Harris** as vice-president in charge of planning, and **Wallace T. Gray** as general works manager. Harris had been vice-president and general works manager for the firm, a division of Clevite Corp., since 1948. Gray comes to Brush from the Leece-Neville Co.

Richard B. Frank has joined the technical division of Nuclear Instrument and Chemical Corp., Chicago, as project engineer. He was formerly an electronic engineer at Chicago U.'s Institute for Nuclear Studies.

Isotope Products, Inc. of Houston, Tex., has named **E. G. Fritz** as general manager.

Adm. Albert G. Noble USN (ret.) has been elected a vice-president of the

Vitro Corp. of America and a member of the board of directors. Prior to his retirement in 1951, he had been Chief of the Bureau of Ordnance for three years.

Bernard F. Herberick has been named director of the newly-formed Information and Education Division at the National Industrial Conference Board. An NICB executive since 1946, he was formerly director of the Education Division. NICB also announced appointment of **Louis A. Allen** to be assistant director of Personnel Administration, and **J. Frank Gaston** as assistant director of Business Economics.

Berkeley Division of Beckman Instruments, Inc., has a new general manager, **Donald C. Duncan,** who will also continue to serve as general manager of Beckman's Helipot and Arga divisions in South Pasadena. **Thomas Allinson** becomes manager of the Berkeley division at Richmond, Calif.

The National Science Board, governing body of the National Science Foundation, has elected **Detlev W. Bronk** as chairman. Bronk, president of the Rockefeller Institute for Medical Research, succeeds Chester **I. Barnard. Paul M. Gross,** vice-president and dean of Duke University, is the new vice-chairman and chairman of the executive committee.

Charles Crompton, assistant director of the AEC Isotopes Division at Oak Ridge, has joined the National Lead Co. of Ohio as associate technical director.

Robert Teitel, who has been working on the LMFR at Brookhaven, joined Dow Chemical but will continue his work at BNL during this year as a visiting scientist.

Afco Products announced the appointment of **Paul N. Strobell** as marketing manager for atomic energy products. Strobell's appointment as first sales manager for nuclear products marks an expansion of the company's atomic activities.

Anton Electronics Laboratories has named **Myron Youdin** vice president and assistant director of research and development, and **Adolph Lovoff** general manager of the instrument division.

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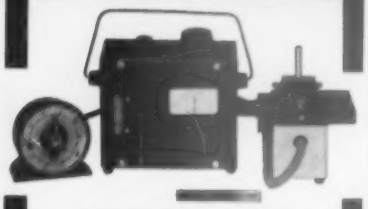

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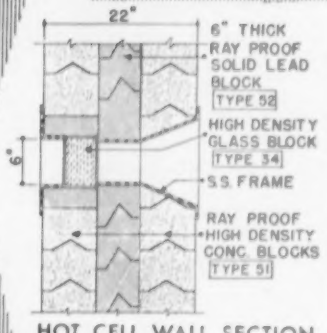

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Radiation Damage to Processing Reagents An important factor in reprocessing nuclear fuels is the radiation damage to process reagents. Chemical changes produced by radiation can affect performance and even feasibility of certain processes. Thus reported G. I. Cathers of Oak Ridge National Laboratory at last month's Nuclear Engineering and Science Congress at Cleveland.

In support of this statement Cathers presented the results of studies of the radiation effect. For Dowex-50 resin the loss in capacity was 15–35% per watt-hr of energy absorbed per gram of resin. For Dowex 1, an anion-exchange resin, the capacity loss was 40%, while for Dowex 30 it was only 1%.

The usefulness of tributyl phosphate-naphtha solvent as an extractant for U, Pu, and Th is limited by radiation damage. A dose of 0.5 watt-hr/l cuts the Ru decontamination factor in half, and 10 watt-hr/l makes the process unworkable due to emulsification and the formation of insoluble Th compounds.

Counting Suspensions in Liquid Scintillators The range of applications of in-solution liquid-scintillation counting will be greatly broadened by new techniques for counting suspensions. Formerly the technique employed was limited to compounds that could be dissolved in the liquid-scintillation solution without affecting its properties too severely. Suitable compounds tended to be organic, limiting the isotopes counted to tritium and carbon-14.' Now Hayes, Rogers, and Langham of Los Alamos Scientific Laboratory report the counting of sulfur-35 and calcium-45 as well as tritium and carbon-14 in suspensions of insoluble particles. While quenching is not a problem, self-absorption and settling are. The new technique was also used to count lyophilized bacteria and pulverized tissue.

A complete account will be presented in an article in a forthcoming issue of NUCLEONICS.

Surface Irradiation Affects Plasticity Alpha-particle irradiation of the surface layers of a metal can affect what is regarded as a bulk property. E. Schmid and K. Lintner of the Institute of Physics, University of Vienna, Austria, investigated the effect of polonium alphas on the creep of zinc single crystals. The crystals were in form of wires approximately 1 mm in diameter and 300 mm long. Creep was tested in a modified Polanyi apparatus. The constant load was 175 gms/mm² and the test temperature was 25° C. The zinc crystals were exposed to alpha irradiation for 60 seconds then allowed to recover for 180 seconds. The same cycle was repeated several times. Tests for control purposes were made with unirradiated zinc single crystals.

The creep of the unirradiated crystals was considerably higher than that of the alpha-irradiated ones. Here are some of the results obtained:

Time (sec)	*Elongation in 10^{-3} mm*	
	Unirradiated	*Irradiated*
60	175	55
120	130	50
180	95	45
240	55	20

Since the depth of penetration of polonium alphas in zinc is not more than approximately 13 microns, the changes in creep under irradiation must solely be due to a surface effect.

Tests with smaller loads showed that the elongation is less, as to be expected, but also that the difference between the elongation of the irradiated and unirradiated specimens decreases with decreasing load.

* * *

This work was reported in Transactions, Austrian Academy of Sciences II, **163**, *109 (1954). Our thanks to Dr. Henry H. Hausner for this account.*

FORD INSTRUMENT

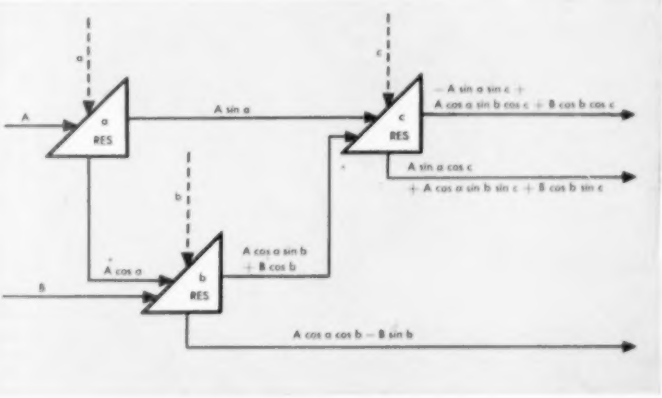
solved one design problem by

CASCADING RESOLVERS WITHOUT ISOLATION AMPLIFIERS

To get around a problem that arises in almost every resolver application Ford engineers recently designed a computer which, among other things, employed a chain of cascaded resolvers to solve complex trigonometric equations, without the use of isolation amplifiers. They solved such an equation as:

$$A \sin a \cos c + A \cos a \sin b \sin c + B \cos b \sin c$$

This was successfully done, without use of vacuum tubes or amplifiers in this circuit:



In view of the widespread use of resolvers to generate sine and cosine functions in modern electro-mechanical analogue computers, it is of great practical significance. Resolvers produced by the Ford Instrument Company have now reached such a high degree of precision, that it is possible to obtain, from an unloaded resolver (which accommodates a single angular quantity only), an accuracy to within less than one tenth of one percent. But most computing circuits call for the use of several resolvers, and once an ordinary resolver is loaded by another resolver, no matter how high its precision, the overall accuracy of the resolver cascade is seriously affected.

The conventional method of avoiding this difficulty is to use an isolation amplifier for each resolver, so that the resolver continues to operate under no-load conditions regardless of the size of the cascade. The importance of cascading without amplifiers is readily appreciated if we realize that the isolation amplifier usually increases the cost of the equipment, more than doubles the size and generates many times more heat that must be dissipated to prevent breakdown of the components. Furthermore, the use of vacuum-tube amplifiers always raises the problem of tube ruggedness and reliability, and requires an additional source of d-c plate voltage.

Have you problems which the engineers at Ford might solve by designing and manufacturing computers, controls or their elements? Write for further information.

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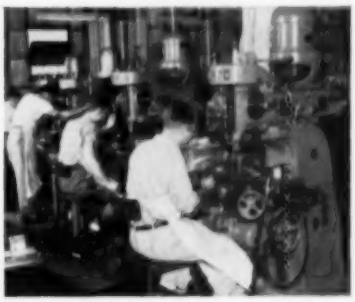
One of the Ford laboratories where a particular design project has called for careful study of resolvers and resolver cascading. Two of the engineers assigned to this project are here checking results. From this work will come one of the new, highly classified weapon systems for the armed forces.



For accuracy and reliability—both vitally necessary in military instruments—experienced machinists must work to fine precision—in the order of .0005 of an inch. Here in one section of the shops of Ford Instrument Company, men are milling parts for an airborne computer.

Typical of Ford Instrument's 40 years of experience in precision control is its work in the field of nuclear power. The Company, for example, is building the control rod drive mechanism for the Seawolf, second atomic submarine. Reactor designs, sensing mechanisms, control equipment and systems, nuclear calculations, and other specialized equipment and abilities are offered by the Company to this expanding industry.

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PATENTS

Determining Radioactivity Percentage Ratios

In U. S. 2,709,754 (assigned to Nuclear Instrument and Chemical Corp.), W. C. Davidon describes how to indicate directly the percentage ratio of the radioactivity of a specimen to that of a standard specimen. The device is simple enough for a person having little experience with radioactivity to operate.

A detector, e.g., G-M or scintillation, is coupled to a scaler of any scaling factor, with suitable input amplifier and pulse-height discriminator. The scaler is coupled to a register (electromechanical or another scaler), having a capacity of 100 or 1,000 counts.

The detector is first exposed to the standard until the register indicates 100 or 1,000. The time for reaching this count is recorded. The scaler and register are reset to zero and the sample counted for the same time interval. The register then indicates the radioactivity percentage ratio.

Quantitative Analysis by X-Ray Absorption

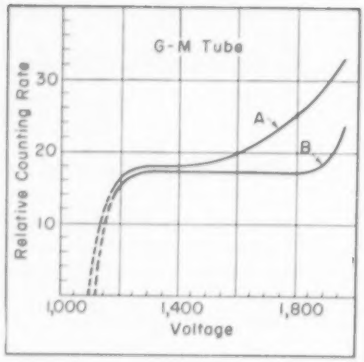
Several applications are suggested: regulation of the X-ray generator power supply, X-ray intensity control, and liquid-level gaging.

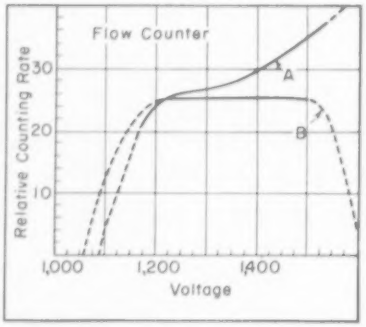
X-ray-absorption quantitative analysis can be done on a routine basis with radioisotopes.

As described in U. S. 2,706,789 (issued to Harold K. Hughes and assigned to Socony-Vacuum Oil Co., Inc.), the radioisotopes should emit monochromatic X-rays, i.e., by *K*-capture, without interfering gamma rays. Optimum results are obtained if the wavelength of the radiation lies near an absorption edge of the element being analyzed for.

An application discussed in the patent is analysis for sulfur in petroleum products (in the range 0.05–2.7%), using Fe^{55}. Corrections are necessary for the presence of other elements than carbon, hydrogen, and sulfur and for large variations in the carbon-hydrogen ratio. For other analyses, isotopes such as Rh^{102}, Cd^{109}, and Ni^{59} are suitable.

The absorption spectrometer described in the patent consists of a radioactive-source holder, a sample cell having beryllium or mica windows, and a G-M-tube detector.





EFFECT on plateaus of G-M counter and gas-flow counter of adding butadiene (0.1% of isobutane pressure) to isobutane-helium mixture. Curves A are for isobutane-helium mixtures, and curves B for added butadiene

Self-Quenched Counters

U. S. 2,712,088, issued to Alfred Whitman and assigned to Tracerlab, Inc., provides an improved gas filling mixture for self-quenching operation of a G-M or a windowless flow counter.

The mixture consists of helium, isobutane, and butadiene. The isobutane is 0.85% of the total pressure, and the butadiene can be 0.05–0.4% of the isobutane pressure. The improved plateau provided by added butadiene for filled and flow counters is shown in the illustration.

It is not clear why the addition of such a minute amount of butadiene should have such a great effect, but it is believed to be attributable to the higher excitation-energy levels of the butadiene conjugated double bonds. However, butadiene alone with helium is not a suitable counting mixture.

* * *

These descriptions are based on abstracts furnished by Melvin Nord, Registered Professional Engineer and Patent Attorney, Detroit, Mich.

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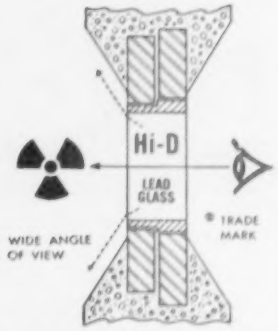

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BOOKS

BOOKS RECEIVED

The Principles of Chemical Equilibrium, by K. G. Denbigh (Cambridge University Press, Inc., New York, 1955, xxi + 491 pages, $7.50). This book on chemical thermodynamics is written for students of chemistry and chemical engineering. The material is presented in three parts: the basic laws and formulas, applications to chemical equilibria, and, lastly, an introduction to statistical mechanics.

Solid State Physics, Vol. 1, edited by Frederick Seitz and David Turnbull (Academic Press, Inc., New York, 1955, xii + 469 pages, $10.00). This is the first in a series of volumes to review advances in research and applications of solid state physics. Although the authorship is international, the articles are written in English. The first-volume topics are: one-electron theory (Reitz), metal cohesion (Wigner), quantum-defect method (Ham), order-disorder transitions in alloys (Muto and Takagi), germanium and silicon (Fan), and electron interaction in metals (Pines).

Magnetic Materials in the Electrical Industry, by P. R. Bardell (Philosophical Library, Inc., New York, 1955, xiv + 288 pages, $10.00). After discussing the development, application, and testing of permanent magnets and soft magnetic materials, this book covers devices such as sound recorders, nondestructive testers, transductors, and transducers. A glossary of terms and units is included.

Laplace Transforms for Electrical Engineers, by B. J. Starkey (Philosophical Library, Inc., New York, 1955, 279 pages, $10.00). To be most accessible to electrical engineers, this material is presented in their language. Not rigorously mathematical, the book is a general introduction to the subject.

Safety in Industry, by D. I. Macfarlane (Philosophical Library, Inc., New York, 1955, 71 pages, $6.00). This illustrated book discussed protective measures to be taken for the safety of industrial personnel. Topics covered are dust and fume control, rotating machinery, press guards, dermatitis, eyes, ionizing radiations, protective clothing, lighting, and flooring.

The Foreseeable Future, by Sir George Thomson (Cambridge University Press, New York, 1955, viii 166 pages, $2.50). On the basis of present scientific knowledge and its future extension and application, the author gives his conception of life, in a technological sense, in the foreseeable future.

Molecular Beams, by K. F. Smith (John Wiley and Sons, Inc., New York, and Methuen and Co. Ltd., London, 1955, x + 133 pages, $2.00). This book is based on Fraser's monograph (1936) on particulate beams. Included in the present book is the resonance method, developed since the earlier monograph.

Transistor Electronics, by A. W. Lo, R. O. Endres, J. Zawels, F. D. Waldhauer, and C. Cheng (Prentice-Hall, Inc., Englewood Cliffs, 1955, xii + 521 pages, $12.00). Beginning with the fundamentals of transistor operation, this book goes on to circuit design. Included are high-frequency operation and circuits, oscillators, modulation and demodulation, and switching circuits.

ALSO OF NOTE

Atomic Age—The Tenth Year. This publication of the International Review Service reviews the Geneva nuclear conference and progress towards establishing an international agency on atomic energy. Other UN activities in atomic energy are summarized. *International Review Service, 15 Washington Place, New York 3, N. Y.*

International Radio Tube Encyclopedia. The 1954–55 edition gives the details of 18,500 tube types. *Dept. IRT, British Industries Corp., 164 Duane St., New York 13, N. Y., $9.00.*

Review of Current Research and Directory of Member Institutions—1955. This biennial edition includes 105 member institutions of the ECRC and 7,500 research projects engaging over 15,000 people. *Renato Contini, Secretary, Engineering College Research Council, New York University, University Heights, New York 53, N. Y., $2.00.*

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So the 20 million homes in need of basic repair and improvements deserve equal attention. The time to stop the spreading blight of slums is *before it starts.*

What's your stake in stopping slums?

If you think your town is different, just look around you . . . If you think slums only affect persons who live in them, think again.

Slums raise taxes and lower property values of the whole town. They raise rates of crime, delinquency and disease. *Everyone* has a real stake in stopping slums. And *that includes you as a businessman.*

Your firm is certainly dependent on the welfare of the community where you do business. But it's more than good business—it's good citizenship to take part in efforts aimed at civic improvements. It's the *responsibility* of every business.

What can your firm do? The answer to America's housing problems starts with individuals. But to roll back slums is such a big job it's going to take more than individual effort. It will need the cooperation of your business and many others.

Some slums should be torn down and a fresh start made. Others can be remodeled and made to conform to better living standards. So it is up to you to support every sound program which seeks adequate housing for all our people.

New help is now available

There is a new national, non-profit organization called A.C.T.I.O.N.—The American Council To Improve Our Neighborhoods—which is designed to help all individuals or groups interested in putting America's house in order.

Send for a free copy of "ACTION." It explains what A.C.T.I.O.N. is and proposes to do. It lists booklets, research, check-lists, and other material which can help you. Address P. O. Box 500, Radio City Station, New York 20, N. Y.

ACTION

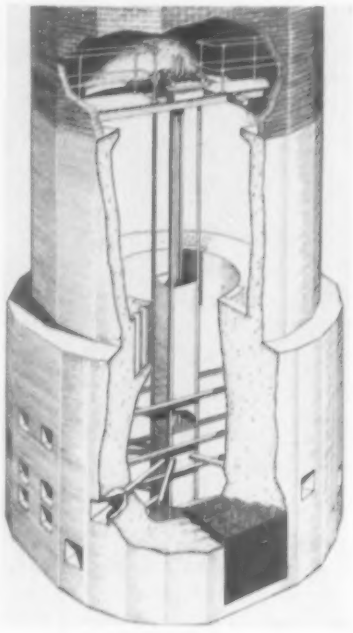
American **C**ouncil **T**o **I**mprove **O**ur **N**eighborhoods

PRODUCTS AND MATERIALS

British Research Reactor

Designed for research and training, this new water-moderated reactor has provision for operating the core at any of three vertical positions. This makes for an efficient use of the available space and provides a large number of experimental facilities including two thermal columns with 4.5-ft-square external faces, a 3 × 3-in. vertical hole through the core, six 12-in. and six 6-in. holes ending as near the reflector face as possible, five 6-in. holes passing through the reactor parallel to a reflector face (for rabbit experiments), four 8-in.-diameter vertical holes for chemical experiments, and a shelf to take a canned experiment over 2-ft cubed.

Power level is 100 kw, peak thermal flux in the core is 1.5×10^{12} n/cm²/sec; epithermal, 6×10^{12}; core gamma radiation is 10^7 r/hr. Peak thermal flux in the reflector is 1×10^{12}. Maximum thermal flux at the end of the experimental holes is 3×10^{11}. Operation at 1 Mw for 5–10 hr, with corresponding increase in flux is possible. Automatic control keeps flux level constant within ±1%.—Associated Electrical Industries & John Thompson, Oak House, Cross St., Sale, Manchester, England.



RADIATION DETECTORS AND ACCESSORIES

Scaler, Ratemeter

SC-3A-103 scaler-amplifier-high voltage supply unit (above) has 20-millivolt sensitivity and instant-reset register. Also available is RM-1B-103 combination with ratemeter in place of scaler.—Technical Measurements Corp., 140 State St., New Haven 11, Conn.

Flo-Window Counter

Model 210 counter has very thin metalized Mylar window that offers low absorption yet isolates sample from counting volume. This prevents undesirable effects such as chamber contamination, vapor effects from moist samples, etc. Plastic window is so thin that it is not gas-tight, consequently a continuous flow of counting gas is required. Also available is model 200A windowless flow counter.—Packard Instrument Co., Box 428, La Grange, Ill.

Lil(Eu) Scintillators

Lithium iodide crystals, europium activated, for slow-neutron scintillation detection and measurement are being mass produced and are now available from stock in 1- and 1½-in.-diameter × ½-in.-thick sizes. Larger sizes available on order.—National Radiac, Inc., Dept. P, 479 Washington St., Newark, N. J.

One-Inch Scintillation Probe

Water-proof high-temperature probe <1 in. i.d. consists of NaI detector, ¾-in. photomultiplier, and preamplifier circuit with 100-ohm output impedance.—National Radiac, Inc., 479 Washington St., Newark, N. J.

Gamma-Ray Logger

New logging unit weighs less than 160 lb with 1,500 ft of cable. Pressure-sealed probe, precision metering pulley, and cantilevered reel design adapt unit to logging core holes.—Moran Instrument Corp., 170 E. Orange Grove Ave., Pasadena 3, Calif.

Fast Electronics

Pulses of 1 milliμsec rise time and 0.001–0.1-μsec (or longer) duration are produced by the model 300 pulse generator. Three or more separate outputs offer variable output from 100 to 0.006 volts in 1 db steps. Impedance level is optional, 50–200 ohms. Companion instrument is model 720 wideband amplifier which offers 20–60-db gain with outputs up to 50 volts (positive) into 1,500 ohms or 10 volts into 200 ohms. Input can be + or −, high or low impedance. A 5–50-volt, fast pulse-height discriminator is included for scaling use.—Electrical and Physical Instrument Corp., 25 W. 43 St., N. Y. 36, N. Y.

Trailer-Mounted Air Monitor

For fallout and reactor stack gases safety checks, complete recorded weather data in addition to a permanent continuous record of radioactivity is possible with the AM-5 trailer-mounted air monitor system that can operate unattended for periods up to 10 days. Gamma-sensitive scintillation counter and G-M beta counter count activity on continuously moving filter-paper strip. Other counters are available.—Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Indiana.

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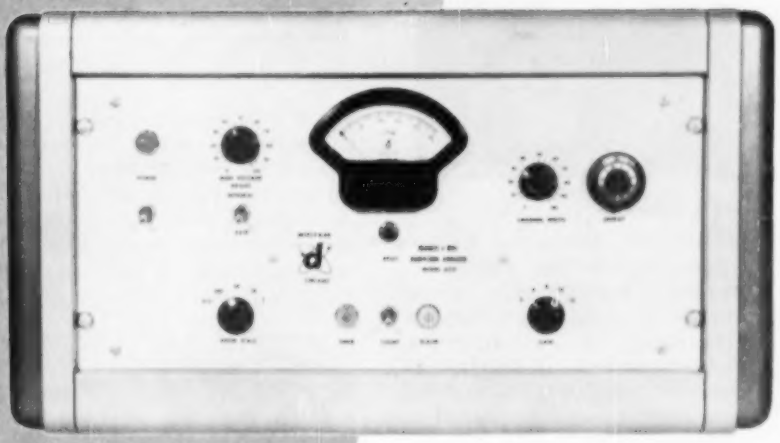
The Original Medical Spectrometer



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Another NEW Detectolab Instrument

Detectolab DZ21
Francis-Bell Spectrometer

This instrument is a combination linear amplifier, count rate meter, high voltage supply and single channel pulse height analyzer. It is ideal for thyroid uptake work; counting Chromium or Iodine in the presence of the other; and scanning for brain tumors.

The front panel has the necessary provisions for setting the voltage, selecting the counting rate range, adjustment of gain, setting the channel base "E" and selecting the window or slit width. It is ideally suited for use with our Model DP21 Scintillation Probe.

SPECIFICATIONS

Window width: Adjustable from 0 to 10 volts.
Span of "E" Dial: 100 volts.
Amplifier Rise Time: 0.3 microseconds.
High Voltage: 600 to 1300 volts positive with 0.1% regulation.
Scale Ranges: 3, 10, 30, 100 counts per second.
Preset Timer: 100 seconds full scale reading.

For further information read November issue of Nucleonics pages 82 to 89

New Directional Feature
Scintillation Probe

Model DP21

The Model DP21 Scintillation Probe has a focusing collimator giving the greatest directional feature of any probe commercially available. Because of its 2" focal length collimator, three-dimensional radiation patterns may be obtained. A focused light beam on the axis of the collimator is included for positioning the probe. The crystal is shielded in all directions, even from the rear by using a light pipe 2" long with a density one-half that of lead.

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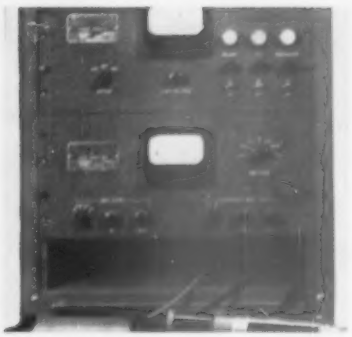
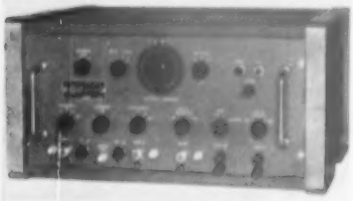


Area Monitor

Model AM-1 (above) was designed for low-drift wide-range operation in continuous measurement of reactor background radiation. Sensitivity for gammas is 0.01–10 mr/hr (ion chamber); for betas, 10–1,000 cpm as registered through a <2 mg/cm² window (TGC-2 counter). Output is direct reading on 3-decade log scales and as series of dots on recording chart (not shown).—Trott Electronics, 27 Gorham St., Rochester, N. Y.



Wide-Band Switch

ES-180A (above) provides d-c to 15 mc dual-trace presentations on any conventional scope at switching rates up to 400 kc. Movable horizontal index, time marker, and amplitude calibrations make accurate comparisons possible. Amplifier rise time is 0.023 μsec; output impedance is 93 ohms.—Teletronics Laboratory, Inc., 54 Kinkel St., Wesbury, N. Y.

Single-Channel Analyzer

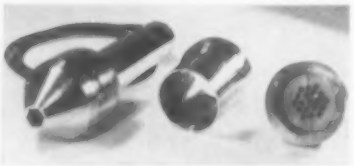
Francis-Bell ORNL design is followed in the C-2900 analyzer (above), which includes amplifier, count-rate meter, power supply, and analyzer. Window width is adjustable from 0 to 10%.—NRD Instrument Co., 6425 Etzel Ave., St. Louis 14, Mo.

Amplifier and Discriminator

Model 652 amplifier has 40–80-db gain flat between 3-db points at 1.7 kc and 5 mc. High and low voltage supplies are included.—Isotopes Developments Ltd., Benham Grange, Aldermaston Wharf, Berks, England.

Digital Recorder

Model Y10 Digi-Graph operates on pulse-rate principles. Paper and punch drives operate in discrete steps. Input pulses can be at rate of 10, 20, or 100/sec. Rates, elapsed time, sampled rates, and many other signals can be measured.—R. N. Auger, 552 Riverside Drive, New York, N. Y.



Focusing Probe

New scintillation probe (above), based on ORNL design (NU, Nov. '55, p. 87), provides sharp directionality and focus permitting probing in three dimensions. Light source aids positioning. Crystal is shielded from the rear with dense 2-in. light pipe.—Detectolab, Inc., 6544 Sheridan Rd., Chicago 26, Ill.

•

Sliding pulser. Model 412 sliding pulser uses mercury-relay pulse generator to give 0.003-μsec-rise pulses which slide in height as precision motor drive turns 10-turn helical pot. —Radiation Instrument Co., Box 733, Silver Spring, Md.

Counting-rate meter. Long scaled mirrored meter matches 3% accuracy of 1–10⁴-cps counting-rate meter with 0.25-volt (−) input sensitivity, and 8% long-term stability.—Devtron Engineering Associates, 1 Winslow St., Redwood City, Calif.

Effluent monitor. Scintillation detector enables the model 2508 water monitor to discriminate in energy and give indication of counting rates in two energy ranges.—Radiation Counter Laboratories, Inc., 5122 W. Grove St., Skokie, Ill.

Linear amplifier. New unit for scintillation and proportional counting has 1-μsec resolving time and includes regulated power supply and 3 high-speed binary counters.—North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, New York.

Portable recorder. Two models with 200- and 10-mv/cm sensitivity, respectively, measure $10 \times 7\frac{1}{2} \times 5\frac{1}{2}$ in. and weigh 12 lb. Standard chart speed is 15 cm/min but chart run-out can be made proportional to depth for well logging.—Douglas and Gierens, Inc., 5516 Cahenga Blvd., N. Hollywood, Calif.

Digital timer, counter. Digitac 1500's ten plug-in decades enable it to count to 10^{10} at rate not over 100 kc or time from 10 μsec to 100,000 sec (27.8 hr) in 10-μsec steps.—Ransom Research, Box 382, San Pedro, Calif.

Low-voltage supply. Model CS-3667 provides three entirely independent tubeless 0–50-volt supplies with 10-milliamp capacity and 0.5% regulation.—NJE Corp., 345 Carnegie Ave., Kenilworth, N. J.

Analyzer modification. The 100-channel PA-3 analyzer (NU, July '55, p. 80) is now available with provision for plotting output on X-Y recorders.—Pacific Electro-Nuclear Co., 8930 Lindblade St., Culver City, Calif.

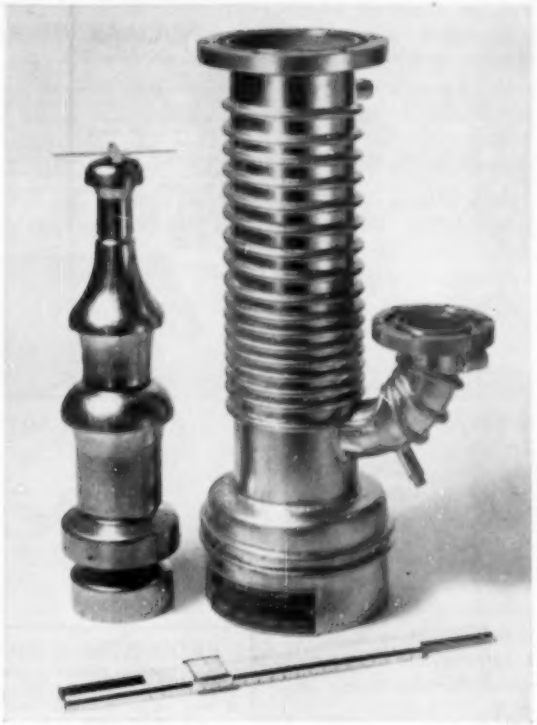
Mercury batteries. Following cells are available singly or in many battery combinations: G-625 (400-milliamp-hr), G-450 (350), RG-1 (1,200), RG-3 (2,200), RG-4 (3,500). —General Dry Batteries, Inc., 13000 Athens Ave., Cleveland 7, Ohio.

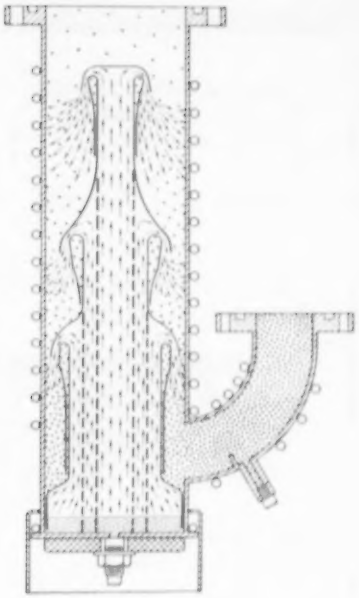
Rate meter. CRM-560 has 5–10,000-cps range full-scale. Linear amplifier and discriminator with 2-mv sensitivity is included, as is 750–2,000-volt supply.—NRD Instrument Co., 6425 Etzel Ave., St. Louis 14, Mo.

Secondary-standard r meters. Seven models measuring from 0.005 to 5,000 r, each designed for 20 to 1,400 kev, are offered.—Landsverk Electrometer Co., 550 W. Garfield Ave., Glendale 4, Calif.

New Cutie Pie. Redesigned version of classic instrument has 500-cm³ ion chamber with 0.7-mg/cm² window for betas down to 40 kev. Instrument has three ranges: 0–25, 0–250, 0–2,500 mr/hr.—Nuclear Chicago, 223 W. Erie St., Chicago 10, Ill.

Fast multiple pulser. Type 1147B provides two positive or negative pulses with 8-millimicrosec rise times and





Typical MCF pump in operation

Hot oil vapor rises through concentric chimneys to nozzles which eject it at supersonic speed in the direction in which a mechanical forepump is removing the gas. Gas molecules diffuse into the high velocity vapor stream from the chamber being evacuated and are propelled forward. The oil vapor condenses on the cooled wall of the pump, returns to the boiler, and repeats the cycle.

Dividing the boiler and the jet assembly into compartments allows the oil to fractionate and purge itself during each cycle. Any dissolved gases or volatile impurities are evolved through the lower jet stages before reaching the uppermost jet. Should these reach the top jet, as they do in an uncompartmented diffusion pump, they could diffuse back into the chamber and cause serious limitations on the ultimate pressure produced in the system.

The pump shown at upper left is the 4" model, type MCF-300. Its speed for air is 290 liters per second; throughput is 800 micron-liters per second; ultimate pressure is 5×10^{-7} mm Hg. Casing is stainless steel construction.

CVC fractionating oil diffusion pumps give you:

1. **low pressures** (10^{-2} to 10^{-7} mm Hg)
2. **high speeds** (65 to 19,000 liters/second)
3. **high throughputs** (100 to 15,000 micron-liters/second)
4. **high limiting forepressures** (up to 400 microns Hg)

If you want to exhaust large gas loads, or gases of low molecular weight to *low* ultimate pressures, there's an MCF pump to do the job.

There are *seven* of these CVC fractionating oil-diffusion pumps, ranging in diameter from 2 inches to 32 inches. Here you have your choice of the widest range of size, speed, and throughput available.

The jet assembly of an MCF pump can be removed easily for cleaning. Jets are plated to prevent rust and reduce heat loss. Large diameter cooling coils insure top operating efficiency. Heaters are mounted externally to facilitate maintenance.

For further information, write for data sheet 6-55.

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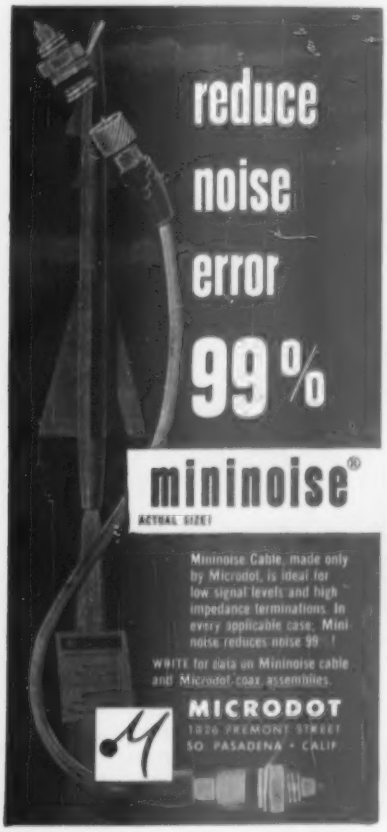
separately variable durations to 1 μsec. Pulse spacing is completely variable in three ranges: ±10, ±2, and ±0.2 μsec. Maximum amplitude with 100-ohm termination is 10 volts.—Fleming Radio Ltd., Caxton Way, Stevenage, Herts, England.

Po sources. Strips of Po in stainless-steel housing provide 250-, 500-, and 1,000-μc ionizing units for static elimination.—Nuclear Products Co., Dept. 56, 10173 E. Rush St., El Monte, Calif.

Regulated supply. PS-22 electronically regulated photomultiplier supply uses thermally-insulated battery voltage reference for long term stability.—Scientific Specialties Corp., Snow and Union Sts., Boston 35, Mass.

Airborne scintillation counter. Completely transistorized circuitry, 200-cpsc/μr/hr sensitivity, and one-man operation are some of the features of this new battery-operated instrument.—Universal Atomics Corp., 19 E. 48 St., New York 17, N. Y.

Single-channel analyzer. Newest addition to complete line of reactor instrumentation is the 1001A, whose window width is constant to 1%.—Daystrom Instrument, Archbald, Pa.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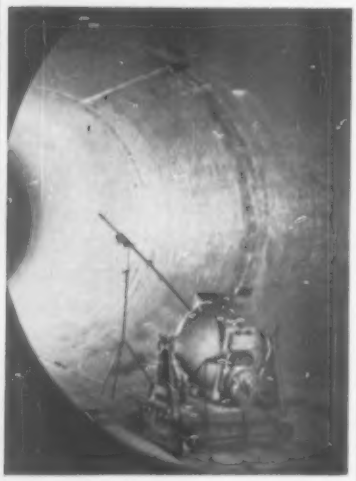

Gamma-Ray Radiography

Pantatron instruments (as above) provide shielded sources of gamma radiation up to 10 c of Co^{60}. Units are available for Ir^{192} and Tm^{170}. Remote positioning controls and storage safes are also offered.—

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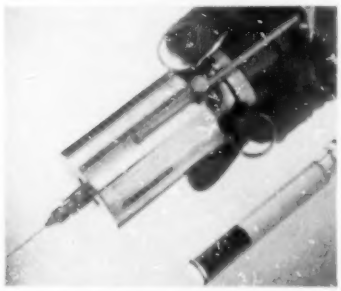
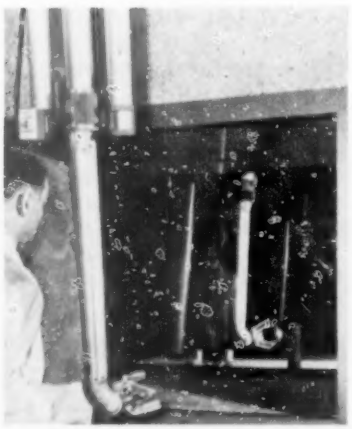
Aluminum-26

Recently discovered long-lived isotope of Al (NU, Dec. '54, p. 62) is now available as Al_2O_3 with a specific activity of 3×10^4 dpm (positrons)/gm. Preparation of carrier-free isotope is underway.—Nuclear Science and Engineering Corp., Box 10901, Pittsburgh, Pa.



Lead-Shielded Syringes

Packing plunger with lead calking wire makes for light weight in this shielded autoclaveable syringe (above). A 10-cc syringe weighs $3\frac{3}{4}$ lb; 2-cc weighs $1\frac{1}{2}$ lb. The $\frac{1}{2}$ in. of lead shielding provides 4 half-value layers for Au^{198} attenuating intensity by a factor of sixteen.—The Hamilton Co., 1134 Whitley St., Whittier, Calif.



Master-Slave Manipulators

Based on Argonne's model 8, new master-slave manipulators can lift up to 30 lb. Z motion is 36 or 39 in. and full slave arm length is about 7 ft. Both left- and right-hand models are available from quantity production.—American Machine and Foundry Co., 261 Madison Ave., New York 16, N. Y.

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Belfab bellows (above) consist of a series of contoured diaphragms, welded alternately at the inside and outside edges to form a stack. Ratio

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Heat Exchangers

New stainless-steel types engineered to industry standards are available in several series and many sizes listed in catalog 1155.—Young Radiator Co., Racine, Wis.

Teflon Packings

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Packless solenoid valve. Line pressure assists closure of 400°-F type-S bronze valve, available in sizes from ½ to 3 in.—Magnatrol Valve Corp., Hawthorne, N. J.

Hoke Swageloked. Needle, toggle, and check valves are now available with Swagelok ends.—Hoke, Inc., 233 S. Dean St., Englewood, N. J.

Air-exhaust hose. Vinyl on outside of Flexaust hose protects against wear in sizes from 4 through 12 in. i.d. Company also makes retractable Portovent duct in 3–36-in. i.d. sizes.—The Flexaust Co., 100 Park Ave., New York 17, N. Y.

Corrosion-resistant faucet. Kel-F sealing rings and trapless design make for a sanitary, fume-tight faucet.—Economy Faucet Co., 12 New York Ave., Newark 1, N. J.

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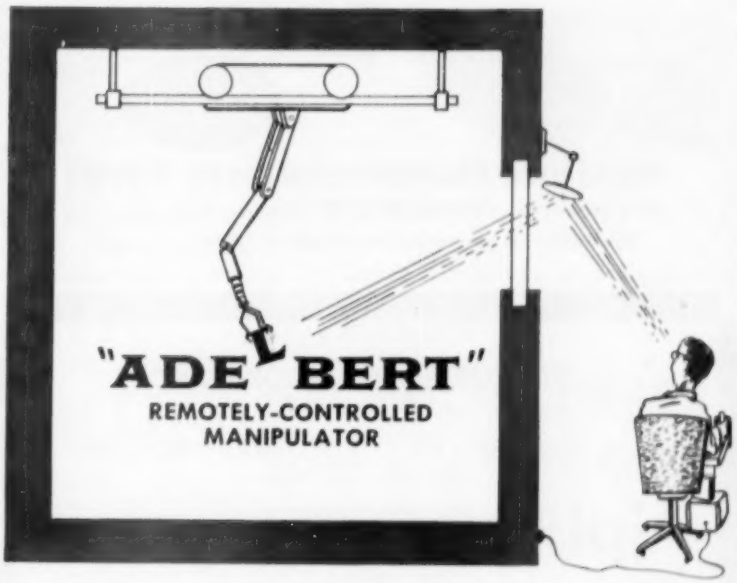

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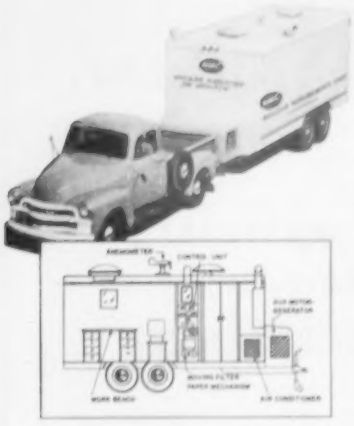

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LITERATURE AVAILABLE

Shielding equipment. X- and gamma-ray protective equipment, including lead-core blocks and high-density windows, are described in new bulletin. 8 p.—Ameray Corp., Route 46, Kenvil, N. J.

Thermocouple gage. Featuring 4½-in. meter, model TC-104 measures 1–1,000 microns.—Electronics Research Laboratories, 85 Surrey St., Brighton 36, Mass.

Flash evaporator. By separating solutions under reduced (~15 mm) pressure, FE2 handles 1.2 l/hr at 50° C.—Arthur S. LaPine and Co., 6001 S. Knox Ave., Chicago 29, Ill.

Program control. Bulletin 1130 describes methods and advantages of automatic, time-condition control. 24 p.—Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Shaped tubing. Data memorandum 17 tells of various shaped tubing (hexagonal, flat-oval, ellipsoidal, etc.) available in welded or seamless versions. 3 p.—Superior Tube Co., 1552 Germantown Ave., Norristown, Pa.

Vacuum pumps. Catalog 425 lists full line of high-vacuum pumps plus engineering data. 52 p.—Kinney Mfg. Div., New York Air Brake Co., 3640 Washington St., Boston 30, Mass.

Electromagnet. Low-cost model 1 variable electromagnet (25,000-Oersted field strength in 0.5-in. gap) is described in brochure.—Diecraft Inc., 8643 Pulaski Highway, Baltimore 21, Md.

Plastic boxes. World's largest assortment of rigid polystyrene boxes is detailed in catalog. 20 p.—Bradley Industries, 1650 N. Damen Ave., Chicago 47, Ill.

Thickness gaging. Instrumentation data sheet 10.9-1a describes use of ElectroniK recorder with Tracerlab thickness gage. 4 p.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne and Windram Aves., Philadelphia 44, Pa.

Gas chromatograph. Model 154 vapor fractometer for analysis of multicomponent mixtures of gases or volatile liquids is described in new brochure. 6 p.—Perkin Elmer Corp., Norwalk, Conn.

Polyethylene sink trap. Data sheet describes new model.—Arthur S. LaPine & Co., 6001 S. Knox Ave., Chicago 29, Ill.

Distilled-water storage tank. Bulletin describes aluminum and tinned-copper tanks.—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

Magnetic cores. Folder gives data on ferramic "H."—General Ceramics Corp., Keasbey, N. J.

Electronic cabinets. Folder with two charts illustrates easy—access slide equipment for electronics.—Grant Pulley and Hardware Corp., 31-85 Whitestone Pkwy, Flushing 54, N. Y.

Pulse transformers. Transformers, inductors, and power supplies for radar and other applications are listed in GEA-5963.—General Electric Co., 1 River Road, Schenectady, N. Y.

Wire-mesh de-misters. Bulletin 16 tells how wire screens separate entrained liquid from vapor phase in chemical processing. 4 p.—Otto H. York Co., 6 Central Ave., W. Orange, N. J.

Mercury batteries. Bulletin describes construction and properties of high-energy-density cells useful in portable radiation instruments. 6 p.—Battery Division, P. R. Mallory & Co., Inc., N. Tarrytown, N. Y.

INDUSTRY NOTES

▶**Internuclear Company,** Clayton, Mo., has been formed to provide, at the outset, consultant services in the reactor field. Philip N. Powers is president, and about half the personnel of the former atomic energy project at Monsanto is now with this company.

▶**Landsverk Electrometer Co.** of Glendale, Calif., has been awarded a Signal Corps contract for production of 55,000 quartz fiber dosimeters. Dr. O. G. Landsverk developed the modern quartz fiber dosimeter which permits measuring total radiation exposure without auxiliary equipment, at Chicago U. during World War II.

▶**Isotopes Incorporated** has been formed to do consulting and measurements in all phases of isotopic application, including precision carbon-14 dating and low-level tritium analysis;

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▶**Fairchild Camera & Instrument Corp.** of Syosset, L. I., has established a nuclear instrumentation department, to be headed by Dr. Harold E. DeBolt. Sales manager will be Louis C. Prisco. The new department will make radiation monitoring equipment, control-rod drive mechanisms, neutron detectors and reactor temperature, pressure and flow controls.

▶**Norden-Ketay Corp.** continued its expansion with establishment of a Western division and acquisition of the **Frohman Manufacturing Company** of Miami, Fla. The Western division, at Gardena, Calif., consists of two plants equipped for research and development as well as quantity production of precision electro-mechanical devices and components for control and computing systems. Arnold Raines will be general manager.

▶**NRD Instrument Co.** (formerly Nuclear Research and Development) has expanded its plant facilities at 6425 Etzel Ave., St. Louis 14, Mo. for production of detectors and counters used in medical and industrial fields. NRD Instrument is a subsidiary of **Nuclear Corporation of America.**

▶**Tracerlab Inc.** reports progress on its 164,000 ft.² new plant at Waltham, Mass. When completed next summer, it will be the country's largest and most modern commercial radioisotope plant devoted exclusively to nuclear pursuits, according to Tracerlab President William E. Barbour Jr.

▶**Colonial Nuclear Industries, Inc.,** has acquired 100% interest in 11 major mineral development properties. They include thorium as well as uranium claims, oil and coal lands. Colonial's operations now range from uranium exploration to the production of precious and base metals, oil, coal, and the manufacture of prospecting instruments.

▶**Atomic Instrument Co.,** Cambridge, Mass., announced it will handle distribution of the Milatomic filter to the atomic energy field. Having 35 million pores, nearly molecular in size, to the square centimeter, the filter is well-suited for use in collection and assay of radioactive precipitates.

▶**Varian Associates,** Palo Alto, Calif., has announced entry into the high-energy radiation business, and is planning construction of its own linear electron accelerator under license from Stanford University.

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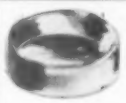

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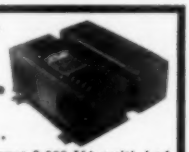

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LETTERS

Correction

DEAR SIR:

I would like to point out several typographical and editing errors appearing in my article "Separating and Purifying Reactor Fuel from Uranium-Ore Concentrates," appearing in the November '55 issue of Nucleonics.

1. Line 1, column 3, p. 68, should read "0.7% of fissionable U^{235}" rather than "0.07%."

2. Line 32, column 3, p. 70, should read "in the raffinate stream" rather than "in the tributyl phosphate."

3. Line 42, column 1 of the section "The Need for Integration," p. 71, should read "Cu" rather than "C."

—WILBUR E. KELLEY
Catalytic Construction Company
Philadelphia, Pennsylvania

NUCLEAR CALENDAR

Jan. 30–Feb. 4—American Physical Society, annual meeting, New York (*Statler*)

Feb. 9—Instrumentation and Control of Industrial Nuclear Processes (N.Y. section, Instrument Society of America), New York (*Statler*)

Feb. 28–29—Fifth Scintillation Counter Symposium, Washington (*Shoreham*)

Mar. 19–21—Reactive Metals Conference (AIME), Buffalo (*Statler*)

Mar. 19–22—Institute of Radio Engineers, annual meeting (Professional Group on Nuclear Science meets on 20th), New York (*Waldorf*)

Apr. 17–18—Regional conference, Atomic Industrial Forum, Atlanta, Ga.

May 14–16—Conference on Basic Mechanisms in Radiobiology (National Research Council), Highland Park, Ill.

June 6–8—American Nuclear Society, annual meeting, Chicago (*Palmer House*)

June 21–23—Society of Nuclear Medicine, annual meeting, Salt Lake City

June 25–29—Am. Soc. for Engineering Education, annual meeting, Ames, Iowa

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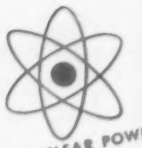

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C-E

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for February issue closing January 18th

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FOR REMOVAL OF RADIOACTIVE DUSTS

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The basis of filter efficiency is the accuracy of the test equipment. Our test machine is periodically compared with government equipment.

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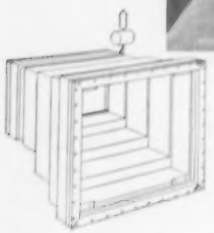
NUCLEONICS

Circulation Dept.

330 W. 42nd St., New York 36, N. Y.

Dimensions of the Corning Standard Radiation Shield Model 800:
Face size, hot side—30" x 36"
Face size, cold side—18" x 30"



Esso scientists watch 3500 curies at work through a *Corning Radiation Shielding Window*

He's watching the world's most radioactive peacetime object.

Between it on the hot side and the scientists on the cold side are layers of dense glass and oil in a cast-iron case. This three-foot-thick window lets researchers see into the hot area clearly and safely.

The protection value of this Corning Radiation Shielding Window is equal to heavy barite concrete with a density of 220 lbs. per cu. ft. Greater or lesser shielding protection to meet your requirements can be had by varying layers of 3.3 and 6.2 density glasses.

Design and Specification Help

You can get this completely assembled Corning window, filled with index oil, ready for installation in wall openings. Also, design assistance is available from Corning for custom windows in any size or style. Individual pieces of glass are available in face sizes up to 70" x 100", in thicknesses up to 9".

For performance data on Corning Radiation Shielding Glasses, write to Atomic Energy Sales Department.

Glass Description – 3 ft. window

Corning Code 8365—Nonbrowning lime glass. Density—2.7 gm. per c.c. Refractive index—1.52.

Corning Code 8362—Nonbrowning lead glass. Density 3.3 gm. per c.c. equals dense concrete for shielding. Refractive index—1.59.

Corning Code 8363—Special high-lead glass. Density 6.2 gm. per c.c. equals iron's shielding protection. Refractive index—1.98.

These glasses have been installed in windows with a total glass path exceeding 200 density inches.

Technical Products Division

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16–1 CRYSTAL STREET, CORNING, N. Y.

Corning means research in Glass

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FOR SCINTILLATION COUNTING

0.02% per day

regardless of line voltage fluctuations

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Front panel receptacle provides either positive or negative high voltage output by use of single front panel switch.

For detailed information on the Model 312 and other Atomic High Voltage Supplies please request Bulletin 300-1.

ATOMIC'S MODEL 312
regulated high voltage supply

SPECIFICATIONS
MODEL 312 1500 Volt Supply

Stability: 0.02% per day

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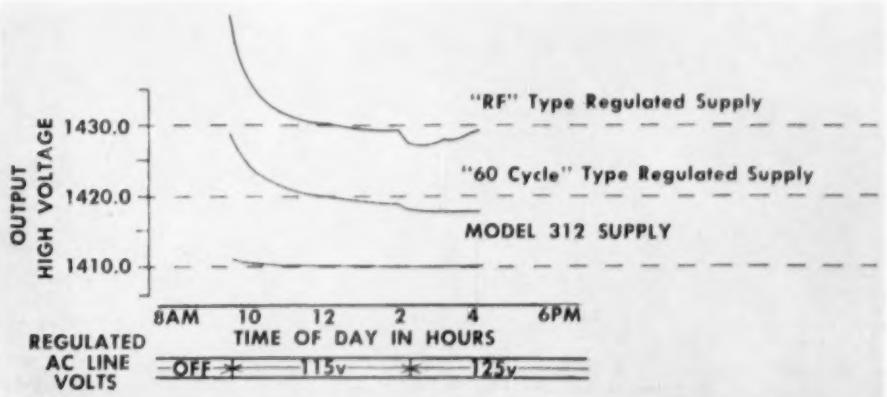

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